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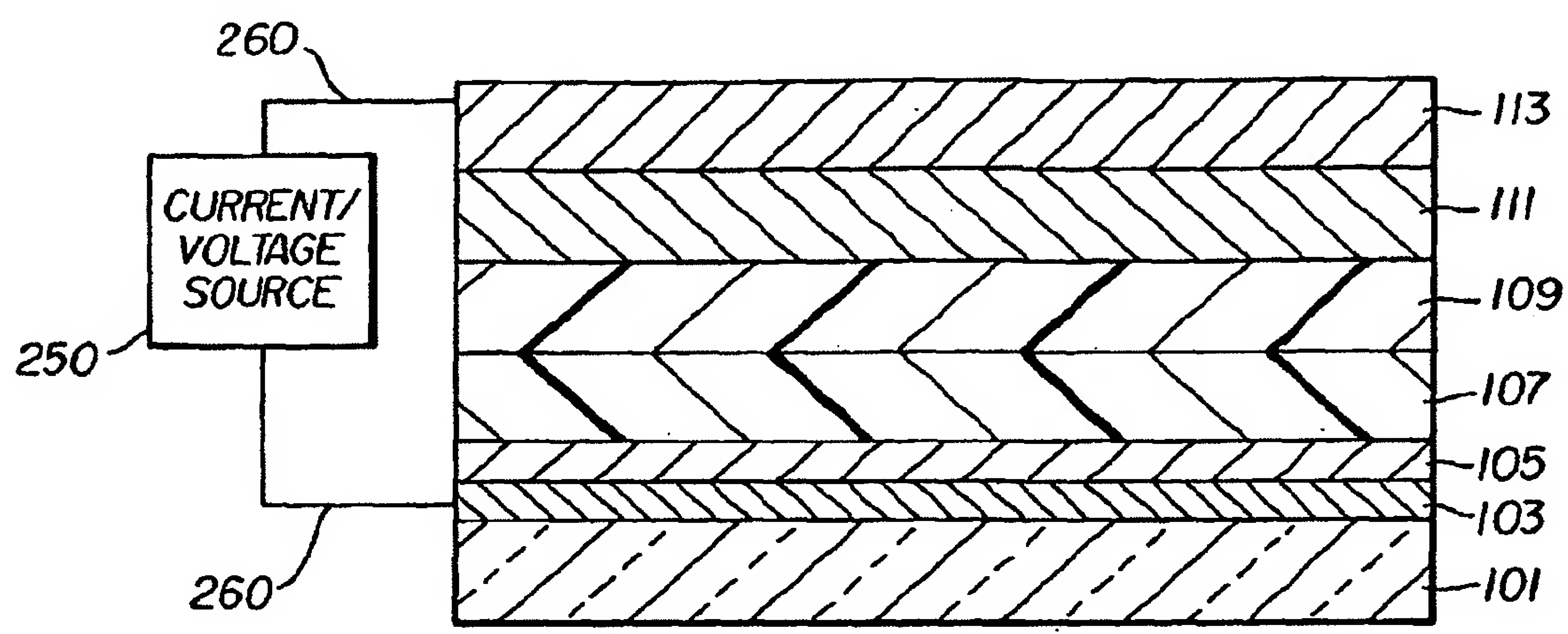
(54) **Title:** COMPLEX FLUORENE-CONTAINING COMPOUNDS AND ELECTROLUMINESCENT DEVICES



(57) **Abstract:** An organic compound comprising a complex fluorene structure represented by one of the following formulas wherein: X_1, X_2, X_3, and X_4 are individually the same or different and include a moiety containing CH or N; R_1, R_2, R_3, and R_4 are substituents each being individually hydrogen, or alkyl, or alkenyl, or alkynyl, or alkoxy of from 1 to 40 carbon atoms; aryl or substituted aryl of from 6 to 60 carbon atoms; or heteroaryl or substituted heteroaryl of from 4 to 60 carbons; or F, Cl, or Br; or a cyano group; or a nitro group; or R_3, or R_4 or both are groups that form fused aromatic or heteroaromatic rings.

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COMPLEX FLUORENE-CONTAINING COMPOUNDS AND ELECTROLUMINESCENT DEVICES

The present invention relates to organic compounds containing a complex fluorene structures.

There is a great need for large area solid state light sources for a series of applications, especially in the file of display elements and lighting engineering. The demands can not be fully satisfactorily met by any of the existing technologies. Electroluminescent device such as light emitting diodes represents an alternative to conventional display and lighting elements. Electroluminescent devices are opto-electronic devices where light emission is produced in response to an electrical current through the device. The physical model for EL is the radiative recombination of electrons and holes. Both organic and inorganic materials have been used for the fabrication of LEDs. Inorganic materials such as ZnS/Sn, Ga/Bs, Ga/As have been used in semiconductor lasers, small area displays, LED lamps, and so forth. However, the drawbacks of inorganic materials include difficulties to process and to obtain large surface areas and efficient blue light.

Organic materials, which includes both small molecules and polymeric materials, offer several advantages over inorganic materials for LEDs, such as simpler manufacturing, low operating voltages, the possibility of producing large area and full-color displays. Conjugated polymers such as poly(phenylvinylene) (PPV) were first introduced as EL materials by Burroughes and others in 1990 (Burroughes, J. H. *Nature* 1990, *347*, 539-41). Tremendous progress has been made since then to improve the stability, efficiency, and durability of polymeric LEDs (Bernius, M. T. and others, *Adv. Mater.* 2000, *12*, 1737). Organic LED (OLED) represents an alternative to the well-established display technologies based on cathode-ray tubes and liquid crystal displays (LCDs), especially for large area displays. OLED has been demonstrated to be brighter, thinner, lighter, and faster than LCDs. Moreover it requires less power to operate, offers higher contrast and wide viewing angle (>165 degree), and has

great potential to be cheaper to manufacture, especially the polymer-based LEDs (PLED).

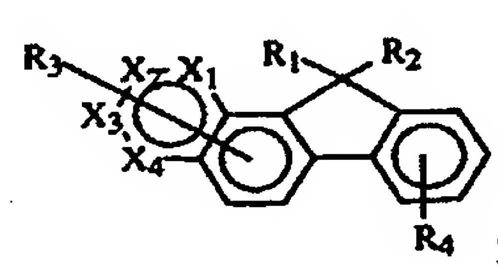
The OLED technology has stimulated intensive research activities across all disciplines. Currently, great efforts in materials research have been focused on novel materials for full-color flexible displays. Full-color displays require three basic colors, red, green and blue, and flexible substrates require low temperature and easy processing of the organic materials. PLED devices show great promise in meeting both requirements, since the emission color can be tailored by modulation of the chemical structures and the solution processing allows for micro-patterning of the fine multicolor pixels via inkjet printing technique (Yang, Y. and others, *J. Mater. Sci.: Mater. Elecron.*, 2000, *11*, 89). However, processable, stable, and efficient blue light emitting organic materials are still highly desirable to meet the challenge. Blue light requires wide energy band. With blue light emitting polymers as primary materials, it is possible to produce other colors by a downhill energy transfer process. For instance, a green or red EL emission can be obtained by doping a blue EL host material with a small amount of green or red luminescent material.

It is an object of the present invention to provide novel highly efficient luminescent materials.

It is another object of the present invention to provide wide energy band gap luminescent materials.

It is a further object of the present invention to provide novel processable materials for easy processing.

These objects are achieved by providing the following organic materials for an organic electroluminescent device. The organic materials comprise a complex fluorene structure represented by one of the following formulae (I), (II), or (III).



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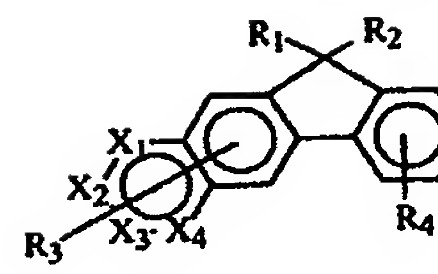
(I)



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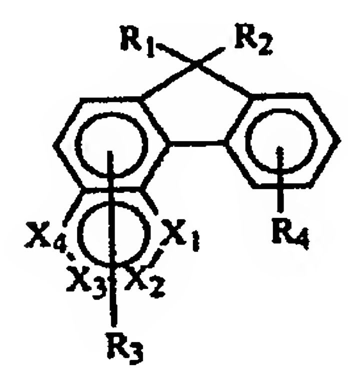
(II)



(III)

wherein:

X_1, X_2, X_3, and X_4 are individually the same or different and include a moiety containing CH or N; R_1, R_2, R_3, and R_4 are substituents each being individually hydrogen, or alkyl, or alkenyl, or alkynyl, or alkoxy of from 1 to 40 carbon atoms; aryl or substituted aryl of from 6 to 60 carbon atoms; or heteroaryl or substituted heteroaryl of from 4 to 60 carbons; or F, Cl, or Br; or a cyano group; or a nitro group; or R_3, or R_4 or both are groups that form fused aromatic or heteroaromatic rings.

The present invention provides organic luminescent materials with a number of advantages that include excellent solubility and thermal stability, good color tunability, high efficiency and low driving voltage.

FIG. 1 illustrates in cross-section a basic structure of an EL device;

FIG. 2 illustrates the absorption (AB) and photoluminescence (PL) spectra of compound 231;

FIG. 3 illustrates the EL spectrum of an EL device fabricated from compound 231;

FIG. 4 illustrates the voltage-current density and luminance characteristics of a EL device fabricated from compound 231;

FIG. 5 illustrates the absorption (AB) and photoluminescence (PL) spectra of compound 206;

FIG. 6 illustrates the EL spectrum of an EL device fabricated from compound 206; and

FIG. 7 illustrates the voltage-current density and luminance characteristics of a EL device fabricated from compound 206.

The present invention provides highly efficient organic light-emitting materials comprising a complex fluorene structure with good color tunability, excellent solubility and thermal stability, and enhanced electron and/or hole transport ability. The complex fluorene is represented by formulae (I), (II), or (III), X_1, X_2, X_3, and X_4 are individually the same or different and include a moiety containing CH or N; R_1, R_2, R_3, and R_4 are substituents each being individually hydrogen, or alkyl, or alkenyl, or alkynyl, or alkoxy of from 1 to 40 carbon atoms; aryl or substituted aryl of from 6 to 60 carbon atoms; or heteroaryl or substituted heteroaryl of from 4 to 60 carbons; or F, Cl, or Br; or a cyano group; or a nitro group; or R_3, or R_4 or both are groups that form fused aromatic or heteroaromatic rings.

For example, R_1, R_2, R_3, and R_4 are independently hydrogen, methyl, ethyl, propyl, isopropyl, butyl, isobutyl, t-butyl, pentyl, hexyl, ethylhexyl, heptyl, octyl, nonyl, decyl, dodecyl, hexyadecyl, cyclohexyl, cyclopentyl, methoxy, ethoxy, butoxy, hexyloxy, ethylhexyloxy, methoxyethoxyethyl, methoxyethyloxyethoxyethyl, phenyl, tolyl, nathphyl, xylene, anthracene, phenanthrene, phenylmethylenephenyl, benzyl, phenoxy, pyridyl, thiophenyl. R_3, and R_4 are groups that form fused aromatic or heteroaromatic rings such as naphthalene, anthracene, perylene, phenanthrene, pyrene, tetracene, pentacene, triphenylene, and benzo[a]pyrene. Preferably, R_1, R_2, R_3, and R_4 are hydrogen, t-butyl, hexyl, 2-ethylhexyl, octyl, 3,7-dimethyloctyl, decyl, heptyl, phenyl, 2-ethylhexyloxy, or 4-methoxypheny; diphenylamino, (4-diphenylamino)phenyl; R_3 forms fused aromatic anthracene, or perylene, or pyrene, phenanthrene, or tetracene, and R_4 forms a naphthalene or anthracene; or R_3, or R_4 or both represent one or more than one substituents.

The organic materials comprising the complex fluorene structure are small molecules or polymers, and can be used in a combination of two or more

thereof. Small molecules include dendrimers and polymers include hyperbranched architecture.

Small molecules comprising the complex fluorene structure are represented by formula (IV)

$$(Y_1)y_1 - \underset{\text{(I), (II), or (III)}}{\text{complex fluorene}} - (Y_2)y_2$$

(IV)

wherein Y_1 and Y_2 each individually represent a substituted or unsubstituted alkyl, alkenyl, alkynyl, aryl, or heteroaryl or other conjugated groups, and y_1 and y_2 are integers from 0 to 6, and Y_1 and Y_2 are the same or different.

Polymers comprising the complex fluorene structure are represented by repeating units of formula (V) which comprise the complex fluorene structure as part of the polymer main chain and repeating units of formula (VI) which comprise the complex structure as part of the polymer side chain.

$$-\!\!\left[\underset{\text{(I), (II), or (III)}}{\text{complex fluorene}} - X_5 - Y_1 - X_6\right]\!\!- \quad ;\ \text{or}$$

(V)

$$\begin{array}{l} -\!\!\left[\text{polymer main chain}\right]\!\!- \\ \quad\quad\quad\quad | \\ \quad\quad\quad (X_5)x \\ \quad\quad\quad\quad | \\ \quad\quad\quad (Y_1)y_1 \\ \quad\quad\quad\quad | \\ \quad\quad\quad \text{complex fluorene (I), (II), or (III)} \\ \quad\quad\quad\quad | \\ \quad\quad\quad (Y_2)y_2 \end{array}$$

(VI)

wherein:

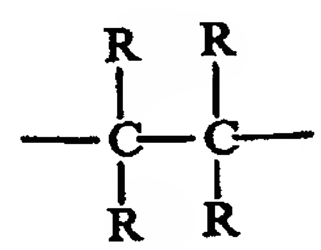
X_5 and X_6 are linking groups, Y_1 and Y_2 are each individually represented as a substituted or unsubstituted alkyl, alkenyl, alkynyl, aryl, or heteroaryl or other conjugated groups, and x, y_1 and y_2 are integers from 0 to 6.

Incorporating Y_1 and Y_2 units into the compounds comprising the complex fluorene structure represented by formula (IV), (V), and (VI) can further improves solubility, or electron or hole transporting mobility, or finely tune the emission color.

X_5 and X_6 each individually represent a linking group and include but are not limited to the following groups:

Group I:

X_5 and X_6 are carbon-carbon bond linking groups:



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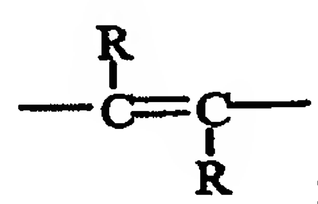


; or

wherein R is hydrogen, alkyl, alkynyl, or alkenyl group containing 1 to 40 carbon atoms; aryl or substituted aryl of containing 6 to 60 carbon atom s; or heteroaryl or substituted heteroaryl containing 4 to 60 carbons; or F, Cl, or Br; or a cyano, or a nitro group;

Group II:

X_5 and X_6 are ether or thioether linking groups:

$$-O-\text{; or}$$

$$-S-$$

Group III:

X_5 and X_6 are ester linking groups:

$$-\overset{\overset{\displaystyle O}{\|}}{C}-O-\text{; or}$$

$$-O-\overset{\overset{\displaystyle O}{\|}}{C}-$$

Group IV:

X_5 and X_6 are anhydride linking groups:

$$-\overset{\overset{\displaystyle O}{\|}}{C}-O-\overset{\overset{\displaystyle O}{\|}}{C}-$$

Group V:

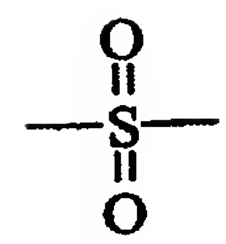
X_5 and X_6 are carbonate linking groups:

$$-O-\overset{\overset{\displaystyle O}{\|}}{C}-O-$$

Group VI:

X_5 and X_6 are sulfone or sulfine linking groups:

$$-\overset{\overset{\displaystyle O}{\|}}{S}-\text{; or}$$



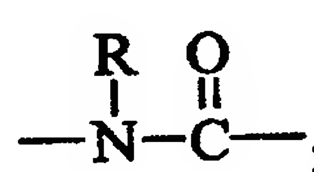
Group VII:

X_5 and X_6 are an amine linking groups:

wherein R is defined as above.

Group VIII:

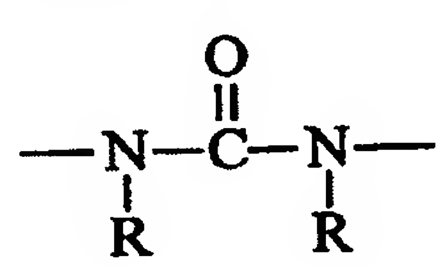
X_5 and X_6 are amide linking groups:



; or

Group IX:

X_5 and X_6 are urea linking groups:



Group IX:

X_5 and X_6 are aryl or heteroaryl linking groups:

$$-\left(Ar \right)_n-$$

wherein Ar is an aryl or substituted aryl group containing 6 to 60 carbon atoms; or heteroaryl or substituted heteroaryl containing 4 to 60 carbons; n is an integer of from 1 to 6.

X_5 and X_6 can be one or the combination of more than one of the above groups.

Y_1 and Y_2 represents a substituted or unsubstituted alkyl, alkenyl, alkynyl, aryl, heteroaryl or other conjugated groups, and can be the same or different.

Alkyl, alkenyl, and alkynyl groups contain 1 to 40 carbon atoms;

Substituted or unsubstituted aryl groups contain 6 to 60 carbon atoms which include phenyl, biphenyl, naphthyl, anthracene, fluorene, phenanthrene, spirophenyl, perylene, or pyrene groups;

Substituted or unsubstituted heteroaryl groups contain 4 to 60 carbon atoms which include pyridine, thiophene, pyrrole, bithiophene, furan, benzofuran, benzimidazole, benzoxazole, quinoxaline, phenylquinoline, dipheyloxadizaole, or carbazole;

All the substituents mentioned above include but are not limited to alkyl or alkoxy groups containing 1 to 40 carbon atoms, aryl or substituted aryl containing 6 to 60 carbon atoms; or heteroaryl or substituted heteroaryl containing 4 to 60 carbons; or F, Cl, or Br; or a cyano group; or a nitro group.

Y_1 and Y_2 can be divided into the following groups.

Group I:

Y_1 and Y_2 are alkyl, alkenyl, or alkynyl groups of formula (VII):

$$-W- \tag{VII}$$

wherein:

W contains 1 to 28 carbon atoms, may also contains O, N, S, F, Cl, or Br, or Si atoms.

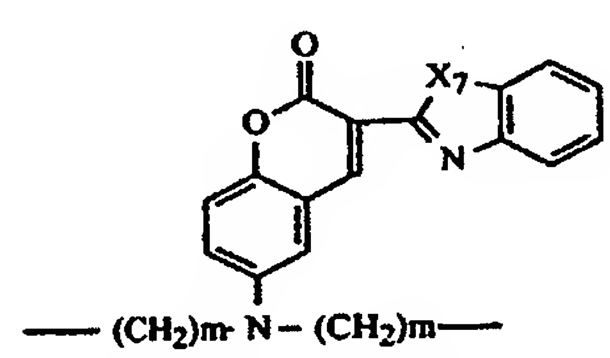
The following structures constitute specific examples of formula (VII)

$$-(CH_2)m-$$

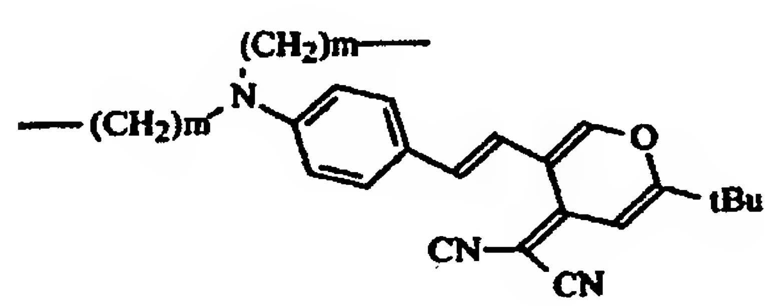
wherein: m is an integer from 1 to 6;

$$-(CH_2)m-\underset{(CH_2)qCH_3}{\overset{(CH_2)qCH_3}{Si}}-(CH_2)m-$$

wherein: q is an integer from 0 to 12;



wherein: X_7 is a C, O, N, or S atom;



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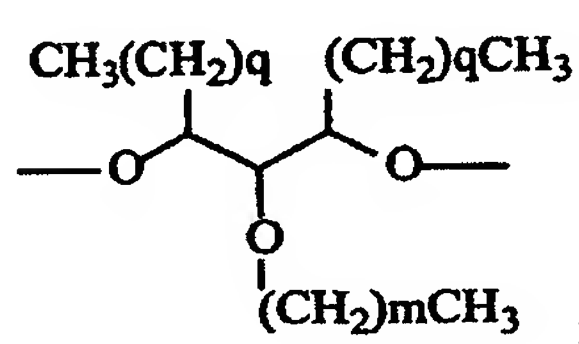
$$-(CH_2)m-\overset{(CH_2)qCH_3}{N}-(CH_2)m-;\text{ or}$$



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Group II:

Y_5 and Y_6 are two aryl or heteroaryl groups connected by a linking group Z of formula (VIII):

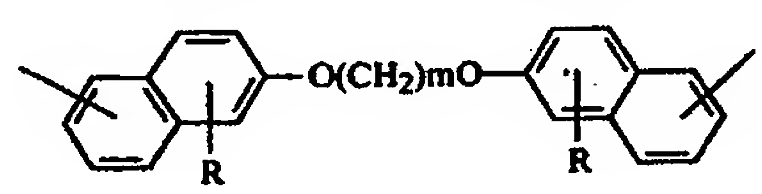
$$—(Ar_1)—Z—(Ar_2)— \quad \text{(VIII)}$$

wherein:

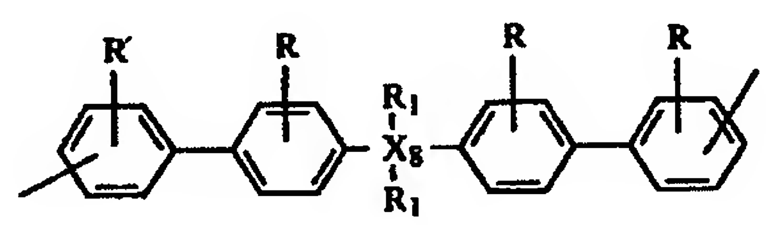
Ar_1 and Ar_2 are substituted or unsubstituted aryl groups containing 6 to 60 carbon atoms, or heteroaryl groups containing 4 to 60 carbons;

Z is a divalent linking groups containing 0 to 40 carbon atoms, can contain N, Si, O, Cl, F, Br, or S atoms.

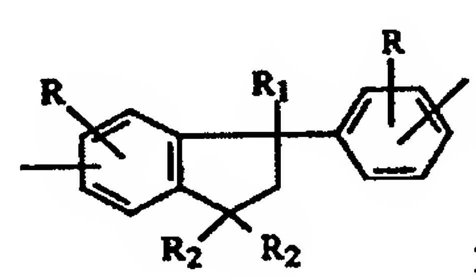
The following structures constitute specific examples of formula (VIII)



wherein: R is defined as above, and can represent more than one such substituent;



wherein: X_8 is C or Si;



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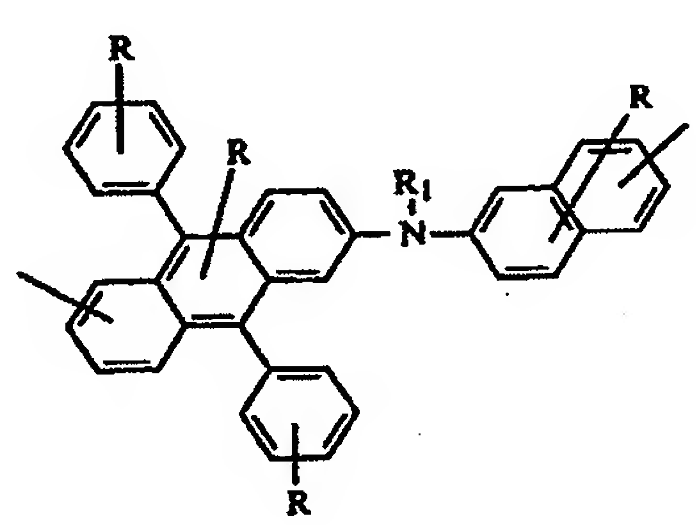

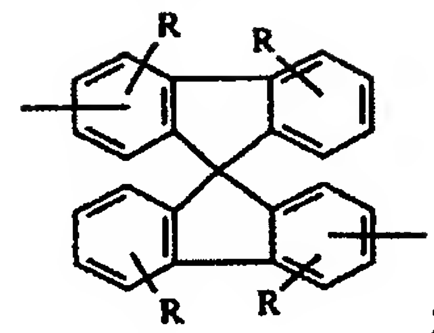

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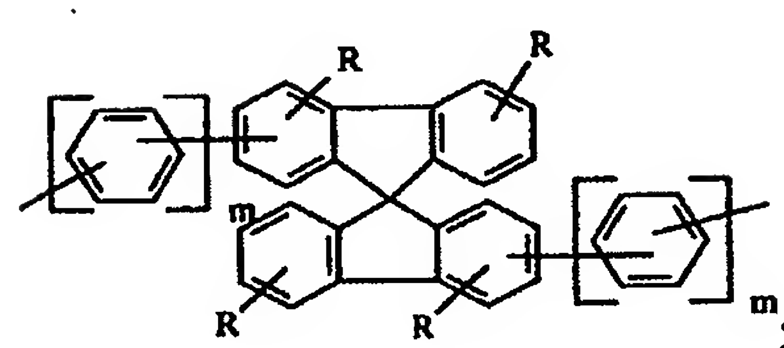

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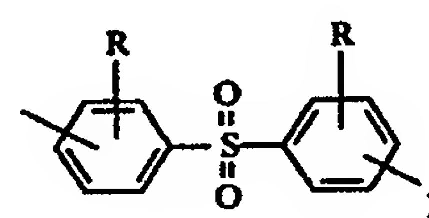

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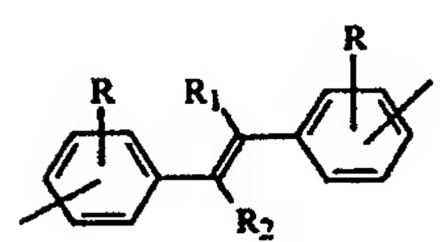

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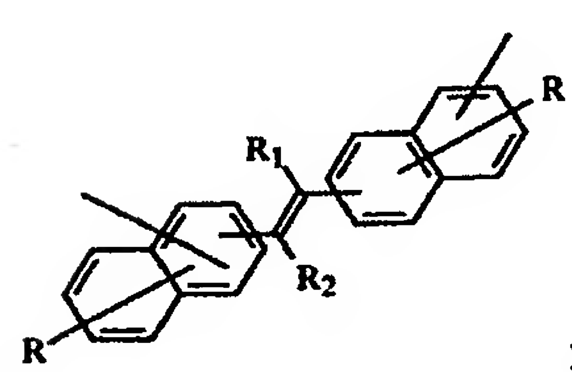

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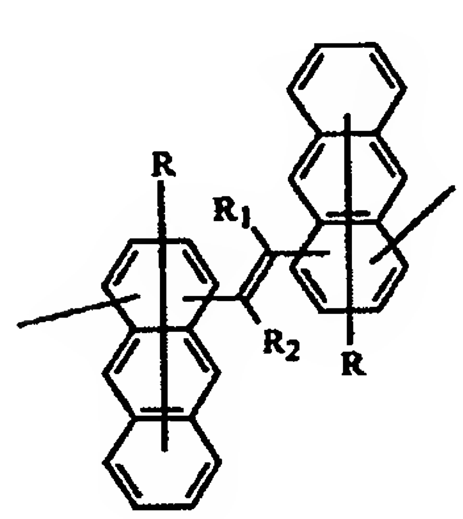

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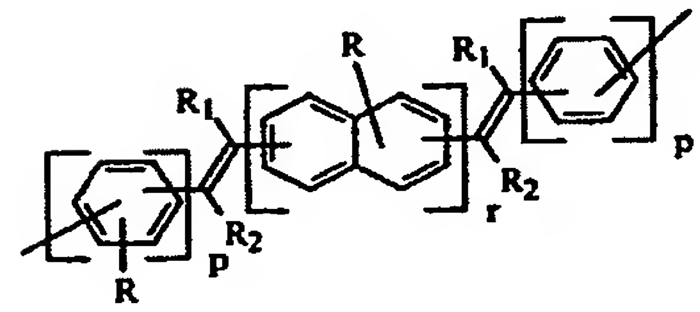
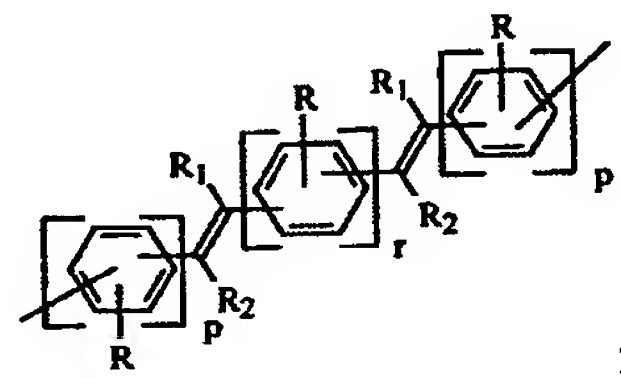


wherein: p and r are integers from 1 to 4;



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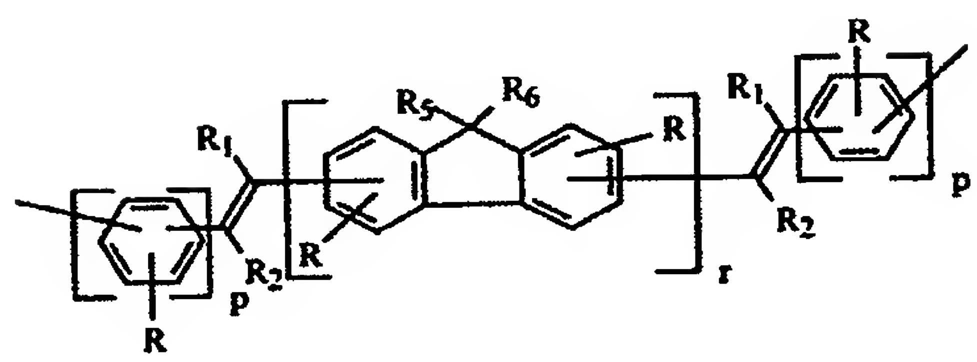
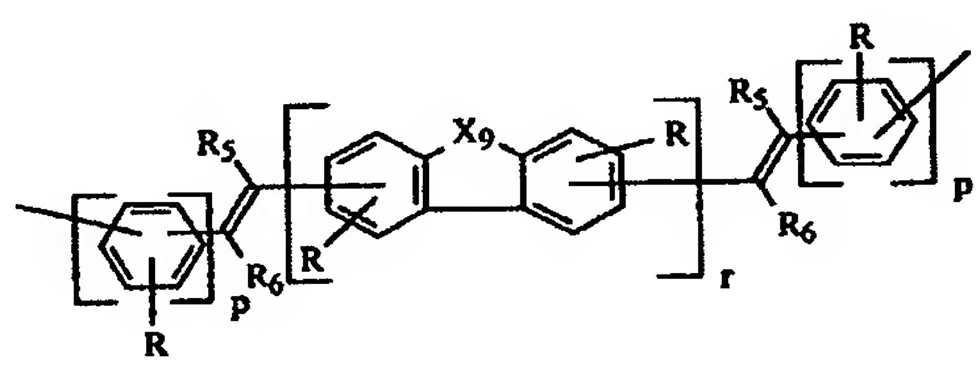


wherein: R_5, and R_6 are substituents each being individually hydrogen, or alkyl, or alkenyl, or alkynyl, or alkoxy of from 1 to 40 carbon atoms; aryl or substituted aryl of from 6 to 60 carbon atoms; or heteroaryl or substituted heteroaryl of from 4 to 60 carbons; or F, Cl, or Br; or a cyano group; or a nitro group; or



wherein: X_9 is O or S atom, or N-R;

Group III:

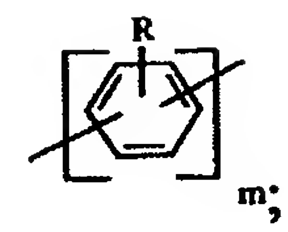
Y_1 and Y_2 are aryl or heteroaryl groups of formula (IX):

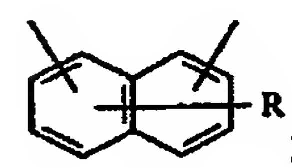
$$—Ar— \qquad \text{(IX)}$$

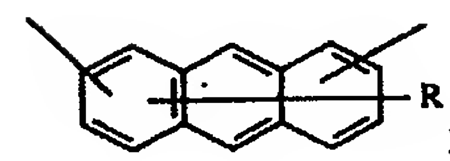
wherein:

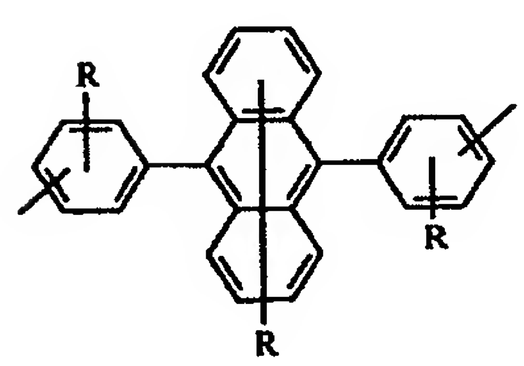
Ar is a substituted or unsubstituted aryl group with 6 to 60 carbon atoms, or a substituted or unsubstituted heteroaryl group with 4 to 60 carbon atoms, and at least one or more N, S, or O atoms.

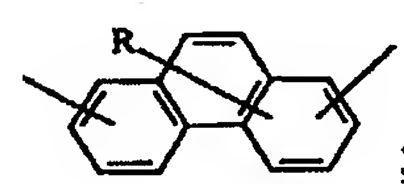
The following structures constitute specific examples of formula (IX)

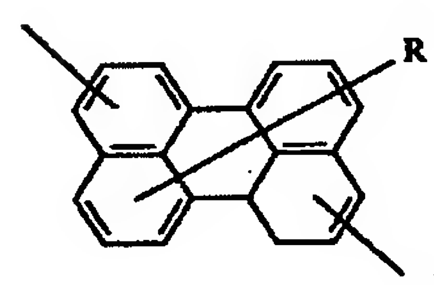
;

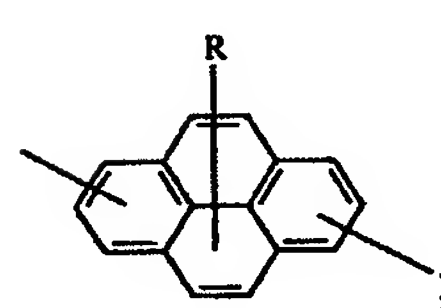
;

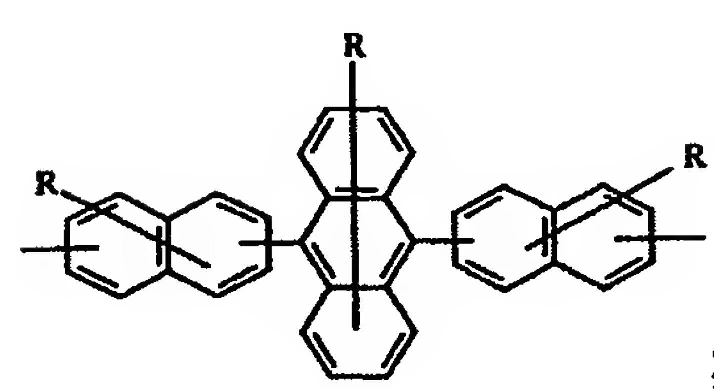
;

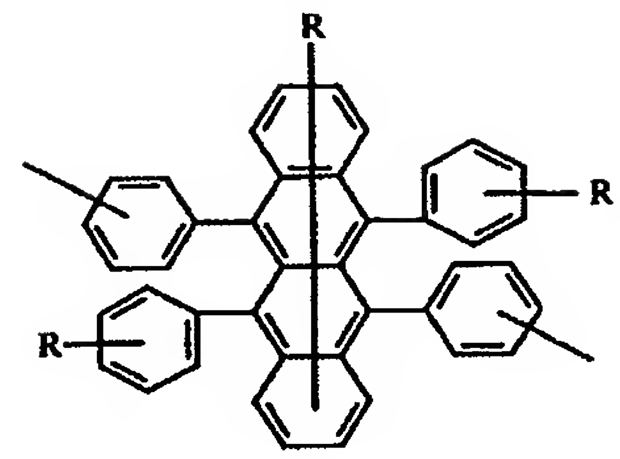
;

;

;

;

;



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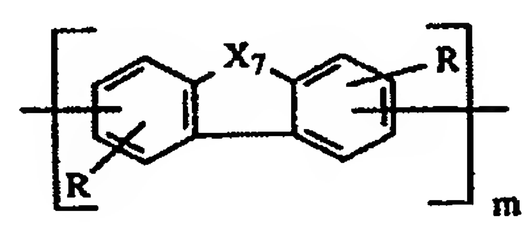

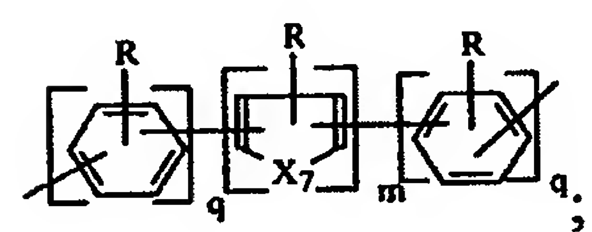

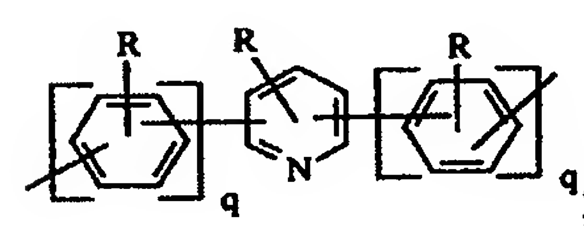

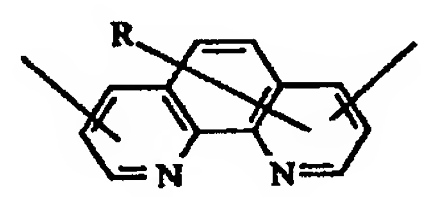

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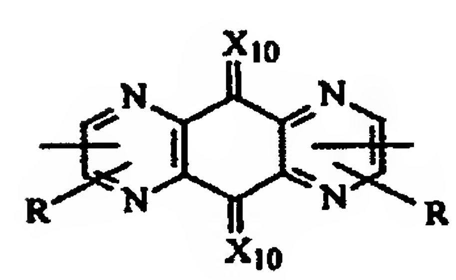
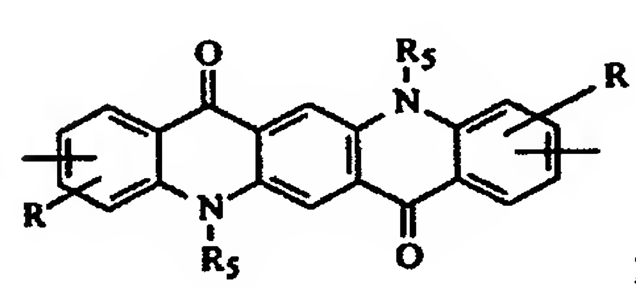


wherein: X_{10} is an O atom or two cyano groups;



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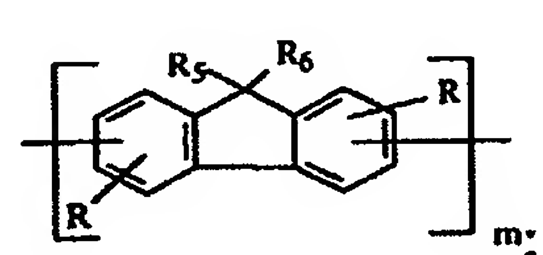

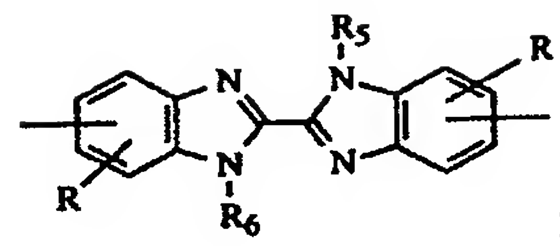

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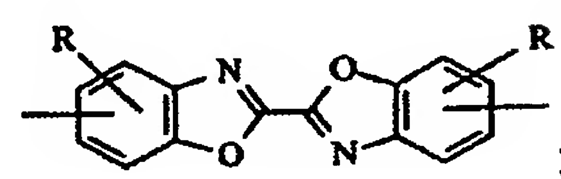

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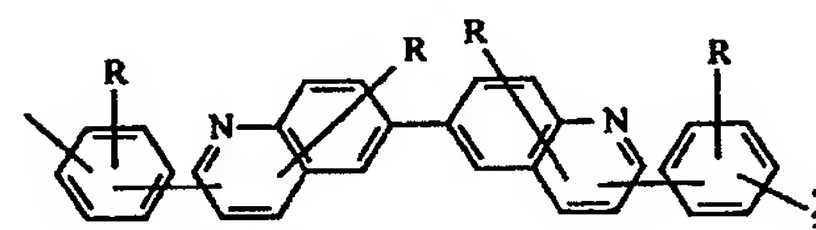

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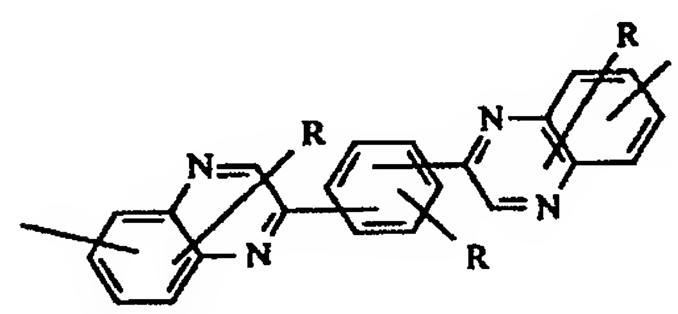

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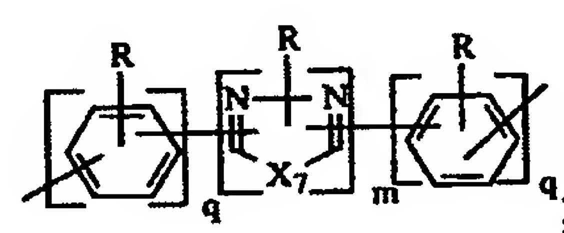

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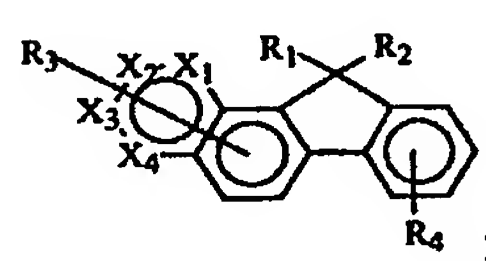

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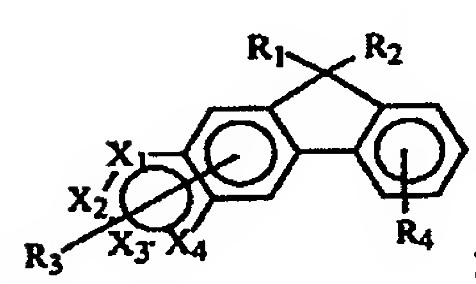
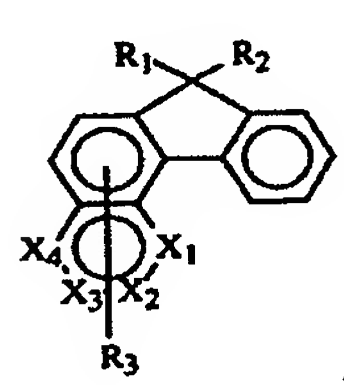


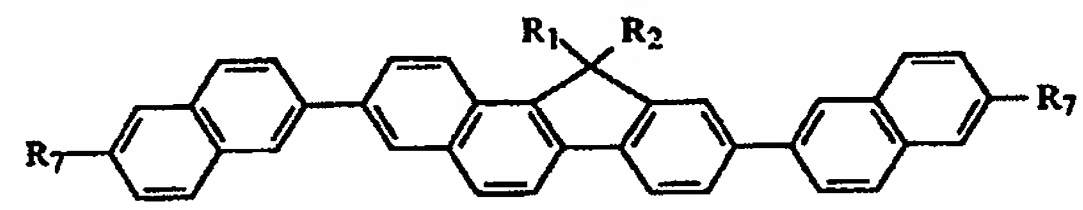
; or



.

Y_1 and Y_2 can be one or the combination of more than one of the above groups.

The following molecular structures constitute specific examples of preferred compounds satisfying the requirement of this invention:

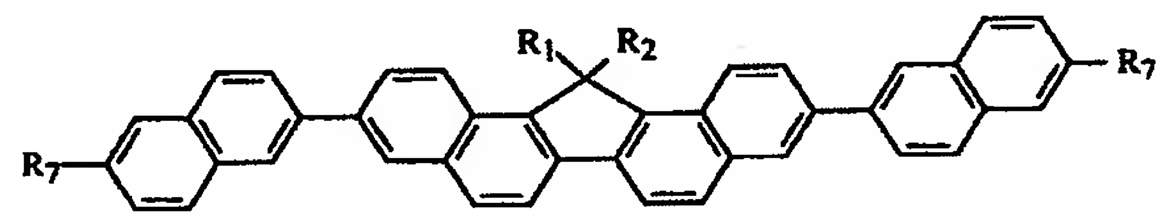


compound 1 $R_1 = R_2 =$ n-hexyl, $R_7 =$ H

compound 2 $R_1 = R_2 =$ n-octyl, $R_7 =$ H

compound 3 $R_1 = R_2 =$ 2-ethylhexyl, $R_7 =$ n-hexyl

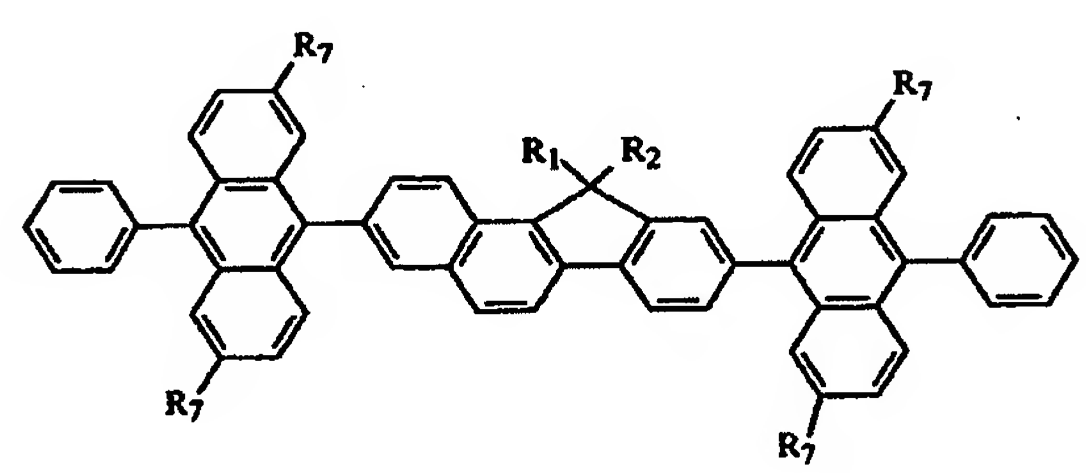
compound 4 $R_1 =$ n-hexyl, $R_2 =$ 2-ethylhexyl, $R_7 =$ H



compound 5 $R_1 = R_2 =$ n-octyl, $R_7 =$ hexyl

compound 6 $R_1 = R_2 =$ 2-ethylhexyl, $R_7 =$ H

compound 7 $R_1 =$ n-hexyl, $R_2 =$ 2-ethylhexyl, $R_7 =$ H

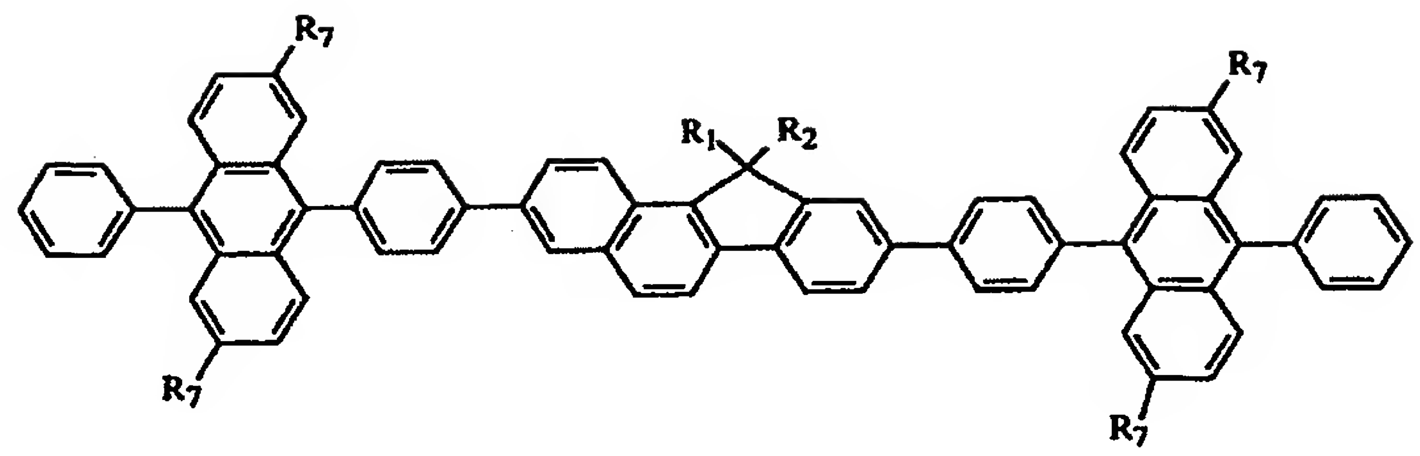


compound 8 $R_1 =$ n-hexyl, $R_2 =$ 2-ethylhexyl, $R_7 =$ t-butyl

compound 9 $R_1 =$ n-hexyl, $R_2 =$ 2-ethylhexyl, $R_7 =$ 2-ethylhexyl

compound 10 $R_1 =$ n-hexyl, $R_2 =$ 2-ethylhexyl, $R_7 =$ 2-ethylhexyloxy

compound 11 $R_1 = R_2 = R_7 =$ 2-ethylhexyl



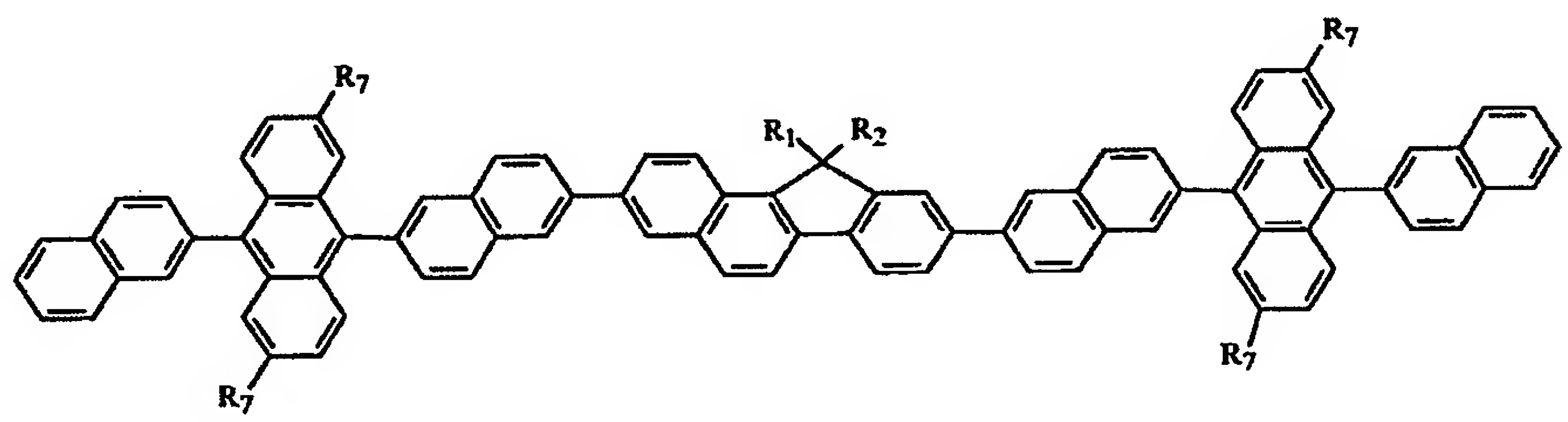
compound 12 R_1 = n-hexyl, R_2 = 2-ethylhexyl, R_7 = t-butyl

compound 13 R_1 = n-hexyl, R_2 = R_7 = 2-ethylhexyl

compound 14 R_1 = n-hexyl, R_2 = 2-ethylhexyl, R_7 = 2-ethylhexyloxy

compound 15 R_1 = R_2 = R_7 = 2-ethylhexyl

compound 16 R_1 = R_2 = 2-ethylhexyl, R_7 = H



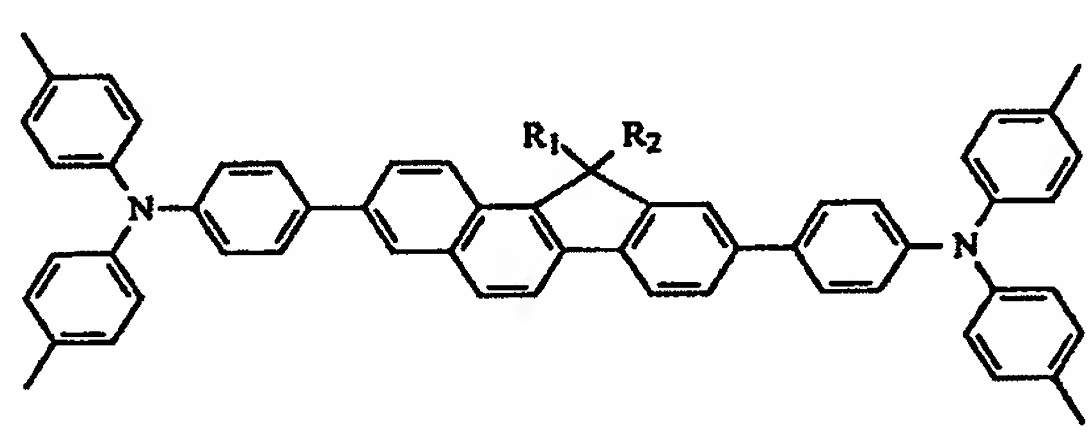
compound 17 R_1 = n-hexyl, R_2 = 2-ethylhexyl, R_7 = t-butyl

compound 18 R_1 = n-hexyl, R_2 = R_7 = 2-ethylhexyl

compound 19 R_1 = n-hexyl, R_2 = 2-ethylhexyl, R_7 = 2-ethylhexyloxy

compound 20 R_1 = R_2 = R_7 = 2-ethylhexyl

compound 21 R_1 = R_2 = 2-ethylhexyl, R_7 = n-octyl



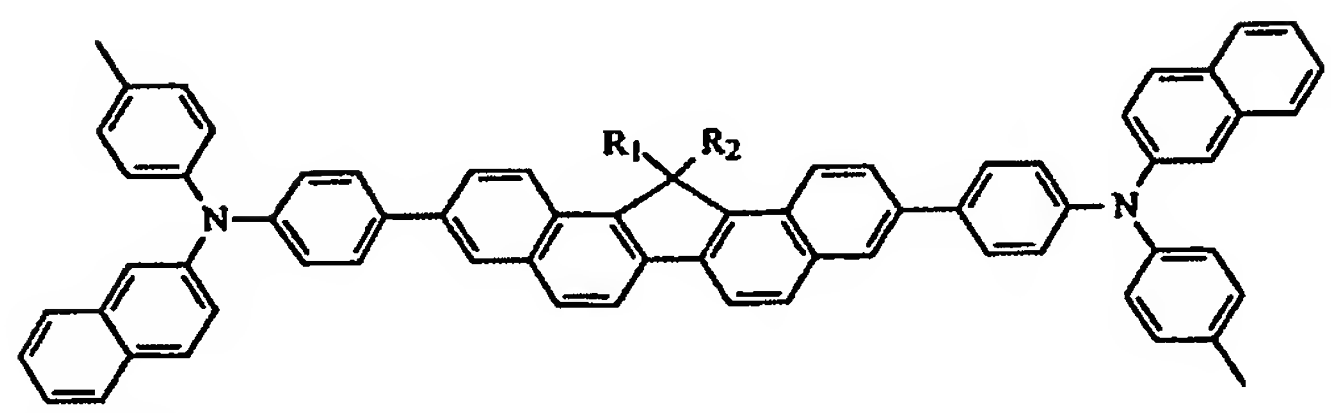
compound 22 R_1 = n-hexyl, R_2 = 2-ethylhexyl

compound 23 R_1 = R_2 = n-hexyl

compound 24 R_1 = R_2 = 2-ethylhexyl

compound 25 R_1 = R_2 = phenyl

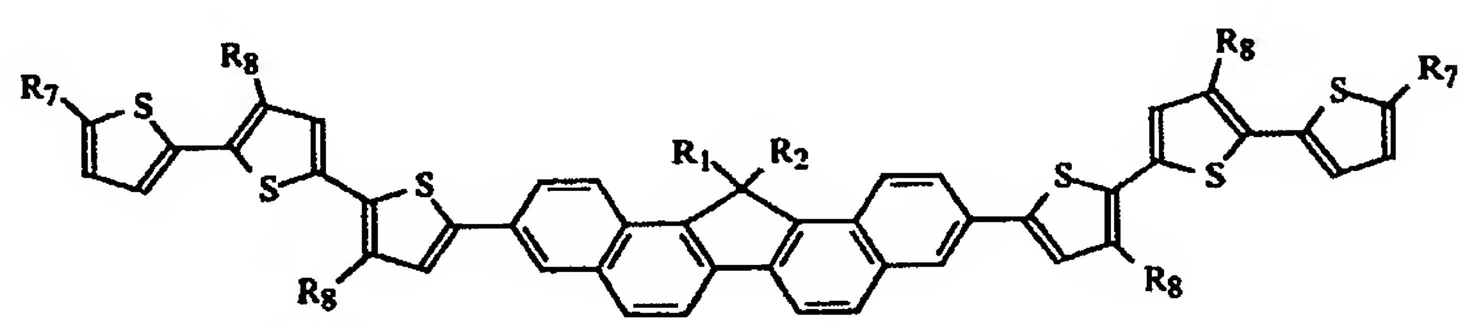
compound 26 $R_1 = R_2 =$ 4-(bis(4-methylphenyl)amino)phenyl



compound 27 $R_1 = R_2 =$ 2-ethylhexyl

compound 28 $R_1 = R_2 =$ 4-(bis(4-methylphenyl)amino)phenyl

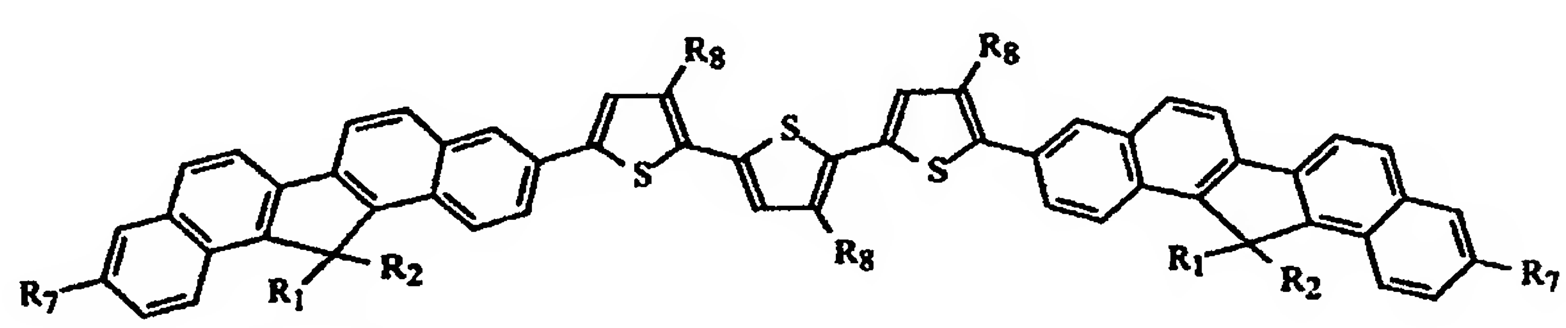
compound 29 $R_1 =$ 2-ethylhexyl, $R_2 =$ n-octyl



compound 30 $R_1 = R_2 = R_7 = R_8 =$ 2-ethylhexyl

compound 31 $R_1 = R_2 = R_7 = R_8 =$ n-hexyl

compound 32 $R_1 = R_7 =$ n-hexyl, $R_2 =$ 2-ethylhexyl, $R_8 =$ H

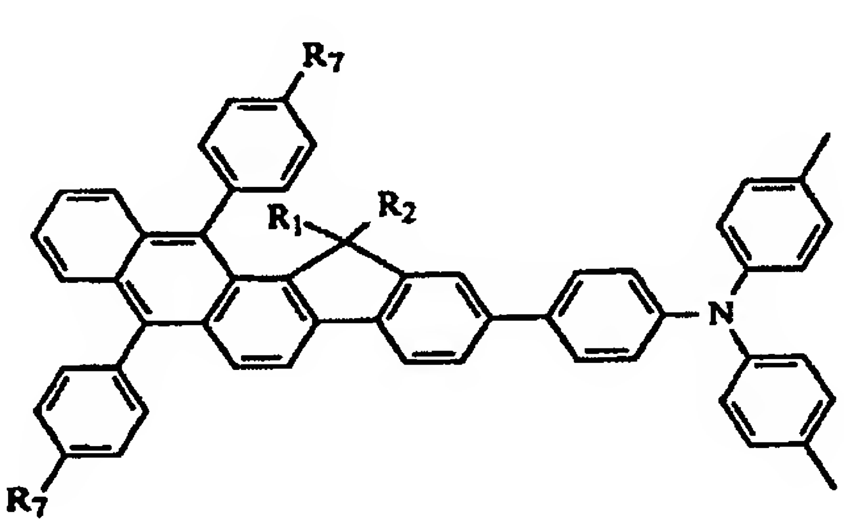


compound 33 $R_1 = R_2 = R_7 = R_8 =$ 2-ethylhexyl

compound 34 $R_1 = R_2 = R_7 = R_8 =$ n-hexyl

compound 35 $R_1 = R_7 =$ n-hexyl, $R_2 =$ 2-ethylhexyl, $R_8 =$ H

compound 36 $R_1 = R_2 = R_7 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_8 =$ n-hexyl



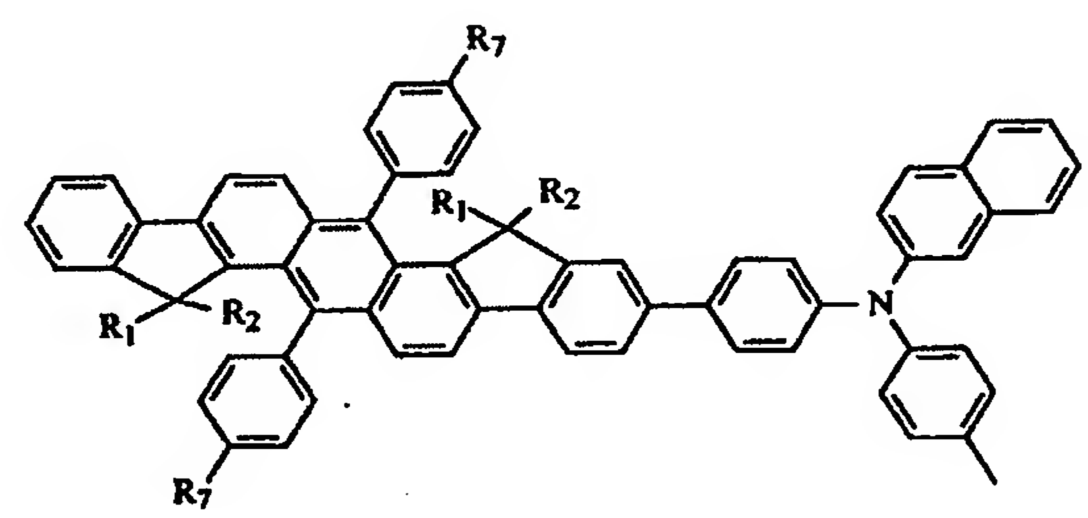
compound 37 R_1 = n-hexyl, R_2 = 2-ethylhexyl, R_7 = t-butyl

compound 38 R_1 = n-hexyl, R_2 = R_7 = 2-ethylhexyl

compound 39 R_1 = n-hexyl, R_2 = 2-ethylhexyl, R_7 = 2-ethylhexyloxy

compound 40 R_1 = R_2 = 2-ethylhexyl, R_7 = 4-(bis(4-methylphenyl)amino)phenyl

compound 41 R_1 = H, R_2 = 4-n-decylphenyl, R_7 = 4-(bis(4-methylphenyl)amino)phenyl

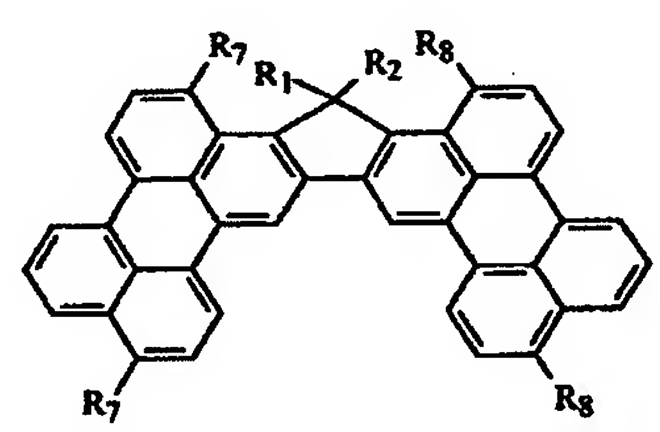


compound 42 R_1 = n-hexyl, R_2 = R_7 = 2-ethylhexyl

compound 43 R_1 = n-hexyl, R_2 = 2-ethylhexyl, R_7 = 2-ethylhexyloxy

compound 44 R_1 = H, R_2 = 4-n-decylphenyl, R_7 = 4-(bis(4-methylphenyl)amino)phenyl

compound 44 R_1 = H, R_2 = 4-n-decylphenyl, R_7 = 2-ethylhexyloxy

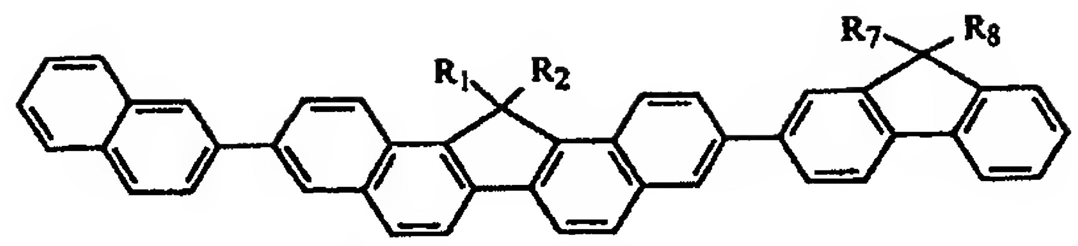


compound 45 R_1 = R_3 = n-hexyl, R_2 = R_8 = 2-ethylhexyl

compound 46 R_1 = n-hexyl, R_2 = 2-ethylhexyl, R_7 = 2-ethylhexyloxy, R_8 = diphenylamino

compound 47 R_1 = H, R_2 = 4-n-decylphenyl, R_7 = R_8 = 4-(bis(4-methylphenyl)amino)phenyl

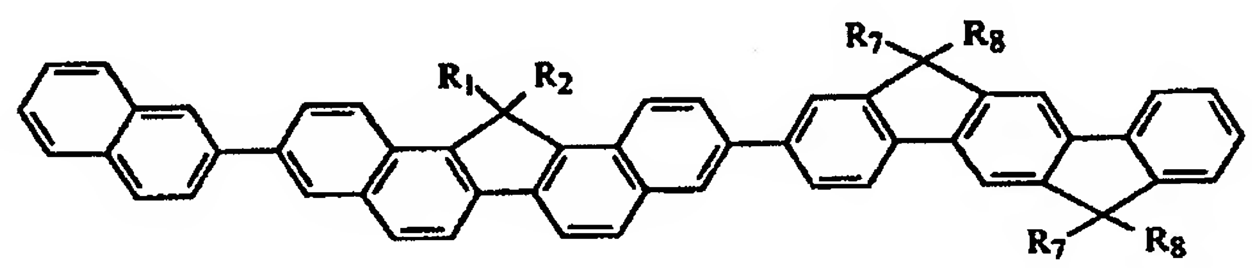
compound 48 R_1 = H, R_2 = 4-n-decylphenyl, R_7 = 2-ethylhexyloxy, R_8 = 4-(bis(4-methylphenyl)amino)phenyl



compound 49 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ 2-ethylhexyl

compound 50 $R_1 = R_7 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 = R_8 =$ H

compound 51 $R_1 = R_2 = R_7 = R_8 =$ 4-n-decylphenyl

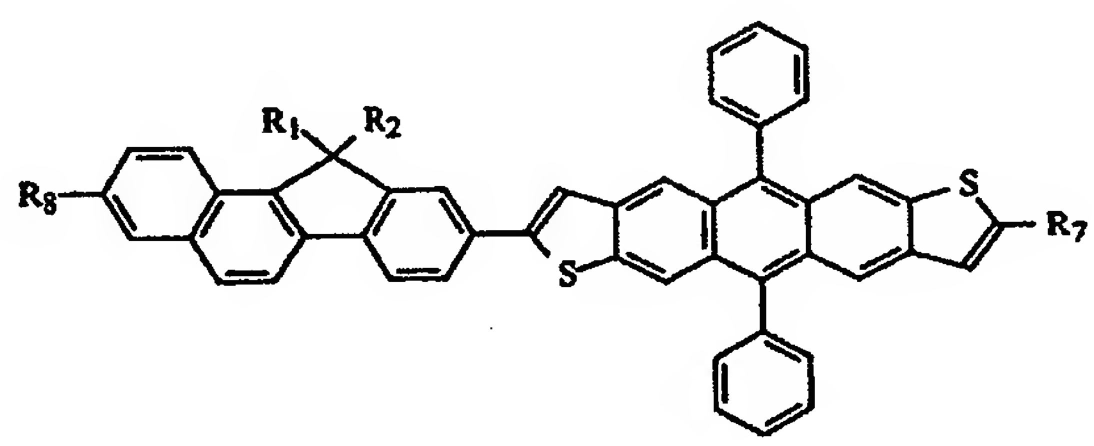


compound 52 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ 2-ethylhexyl

compound 53 $R_1 = R_7 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 = R_8 =$ H

compound 54 $R_1 = R_2 = R_7 = R_8 =$ 4-n-decylphenyl

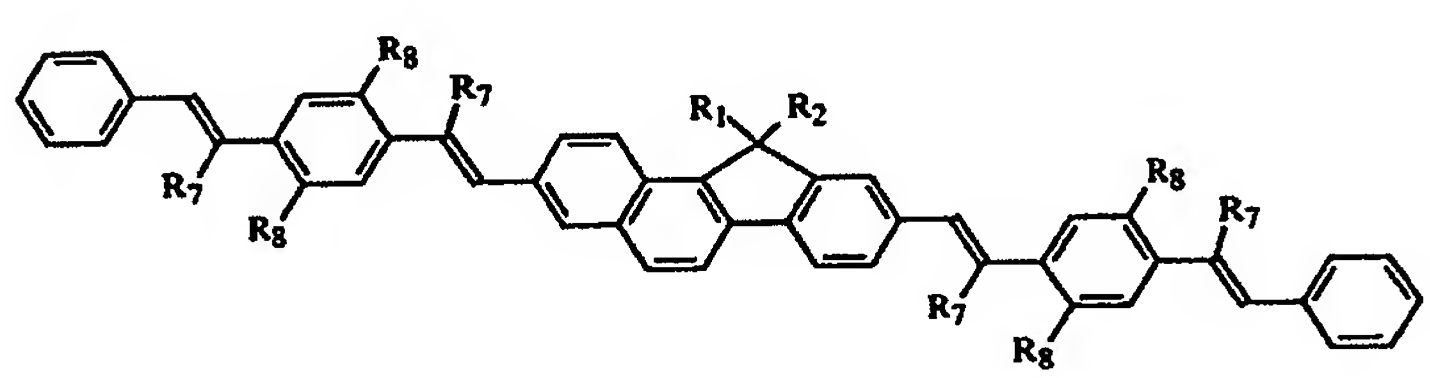
compound 55 $R_1 = R_2 = R_7 = R_8 =$ n-octyl



compound 56 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ 2-ethylhexyl

compound 57 $R_1 = R_2 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_7 = R_8 =$ H

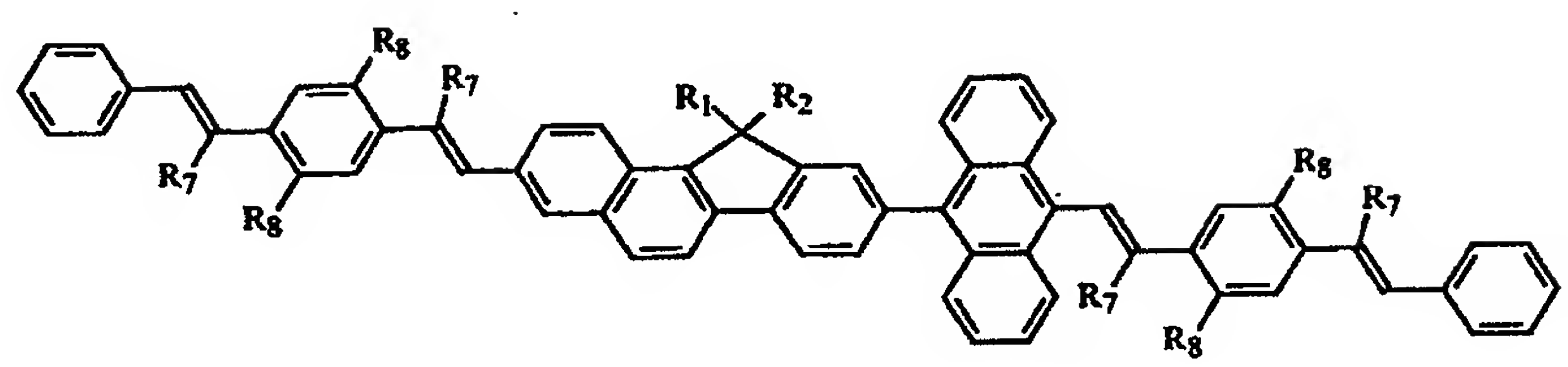
compound 58 $R_1 = R_2 = R_7 = R_8 =$ 4-n-decylphenyl



compound 59 $R_1 = R_2 =$ n-hexyl, $R_7 =$ H, $R_8 =$ 2-ethylhexyl

compound 60 $R_1 = R_2 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_7 =$ H, $R_8 =$ n-hexyloxy

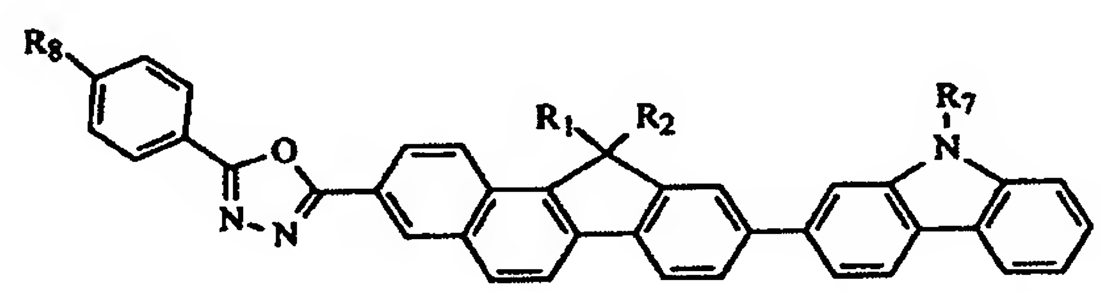
compound 61 $R_1 = R_2 = R_8$ = 4-n-decylphenyl, R_7 = CN



compound 62 $R_1 = R_2$ = n-hexyl, R_7 = H, R_8 = 2-ethylhexyl

compound 63 $R_1 = R_2 = R_8$ = 4-(bis(4-methylphenyl)amino)phenyl, R_7 = H

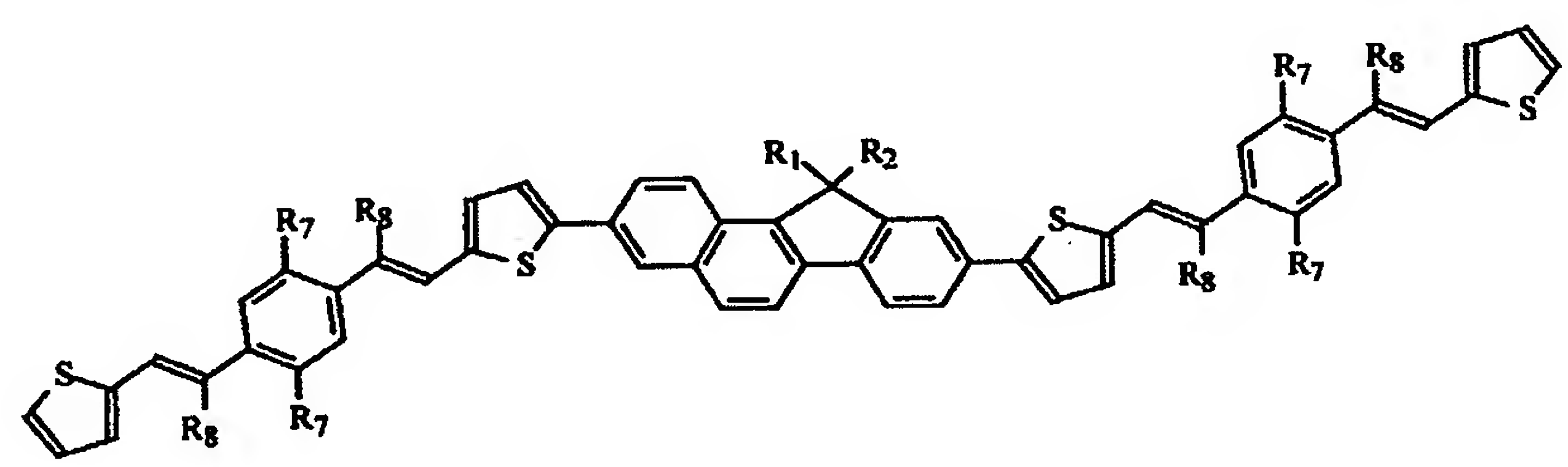
compound 64 $R_1 = R_2$ = 4-n-decylphenyl, R_7 = CN, R_8 = n-hexyloxy



compound 65 $R_1 = R_2$ = n-hexyl, R_7 = 2-ethylhexyl, R_8 = t-butyl

compound 66 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, R_7 = 4-t-butylphenyl, R_8 = t-butyl

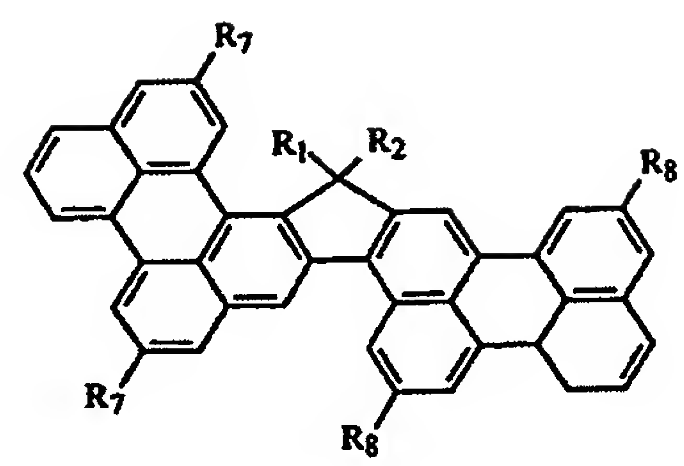
compound 67 R_1 = hexyl, R_2 = 4-n-decylphenyl, R_7 = 2-ethylhexyl, R_8 = phenyl



compound 68 $R_1 = R_2$ = n-hexyl, R_7 = 2-ethylhexyl, R_8 = CN

compound 69 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, R_7 = phenyl, R_8 = H

compound 70 R_1 = hexyl, R_2 = 4-n-decylphenyl, R_7 = 2-ethylhexyloxy, R_8 = phenyl

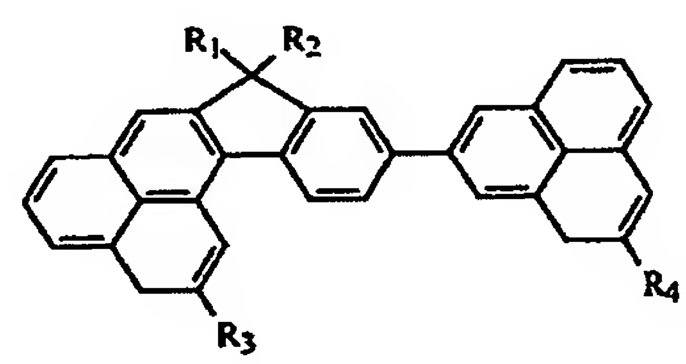


compound 71 $R_1 = R_7$ = n-hexyl, $R_2 = R_8$ = 2-ethylhexyl

compound 72 R_1 = n-hexyl, R_2 = 2-ethylhexyl, R_7 = 2-ethylhexyloxy, R_8 = diphenylamino

compound 73 R_1 = H, R_2 = 4-n-decylphenyl, $R_7 = R_8$ = 4-(bis(4-methylphenyl)amino)phenyl

compound 74 R_1 = H, $R_2 = R_8$ = 4-n-decylphenyl, R_7 = 2-ethylhexyloxy

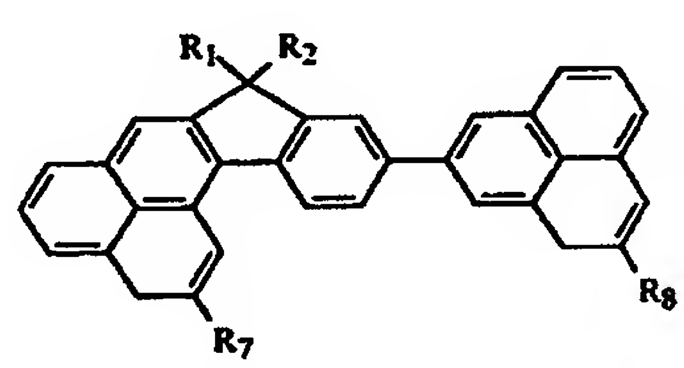


compound 71 $R_1 = R_3$ = n-hexyl, $R_2 = R_4$ = 2-ethylhexyl

compound 72 R_1 = n-hexyl, R_2 = 2-ethylhexyl, $R_3 = R_4$ = 2-ethylhexyloxy

compound 73 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, $R_3 = R_4$ = 4-(t-butylphenyl)

compound 74 R_1 = H, R_2 = 4-n-decylphenyl, R_3 = 2-ethylhexyloxy, R_4 = 2-ethylhexyl

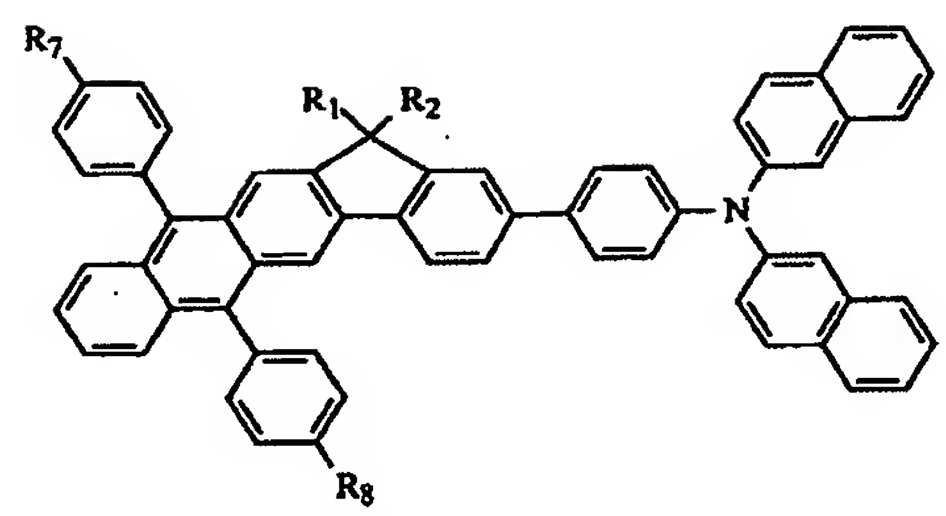


compound 75 $R_1 = R_7$ = n-hexyl, $R_2 = R_8$ = 2-ethylhexyl

compound 76 $R_1 = R_2 = R_7 = R_8$ = 2-ethylhexyl

compound 77 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, $R_7 = R_8$ = H

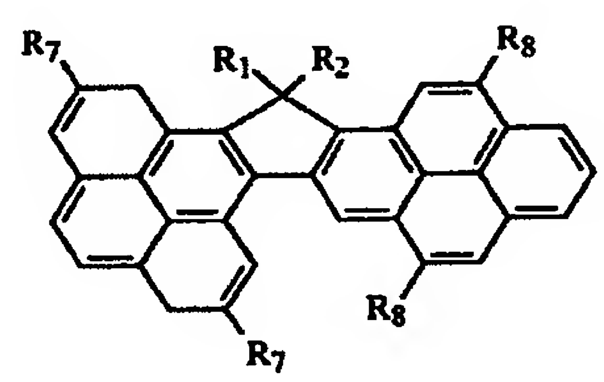
compound 78 R_1 = H, R_2 = 4-n-decylphenyl, $R_7 = R_8$ = 2-ethylhexyloxy



compound 79 $R_1 = R_7$ = n-hexyl, $R_2 = R_8$ = 2-ethylhexyl

compound 80 $R_1 = R_2$ = 2-ethylhexyl, $R_7 = R_8$ = 2-ethylhexyloxy

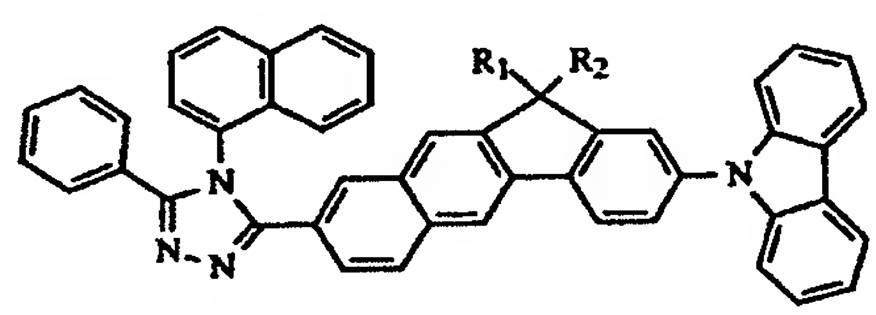
compound 81 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, $R_7 = R_8$ = t-butyl



compound 82 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, $R_7 = R_8$ = t-butyl

compound 83 R_1 = H, R_2 = 4-octylphenyl, $R_7 = R_8$ = 2-ethylhexyl

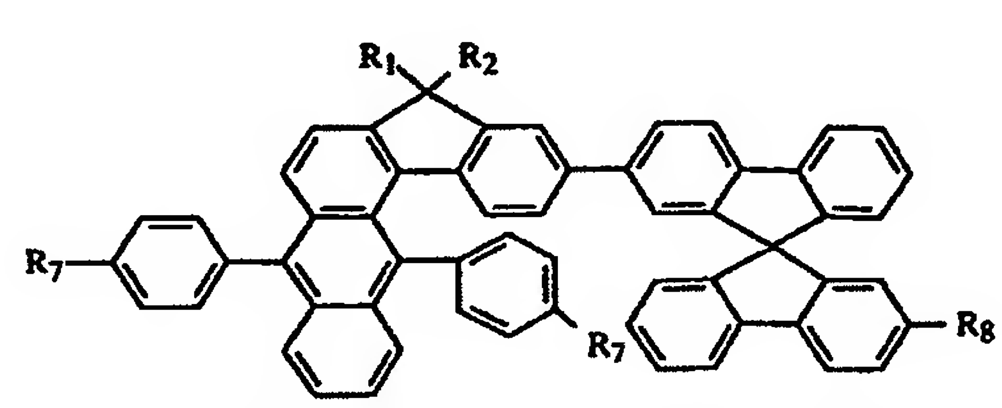
compound 84 $R_1 = R_2$ = 2-ethylhexyl, R_7 = 2-ethylhexyloxy, R_8 = 3,7-dimethyloctyl



compound 85 $R_1 = R_2$ = 2-ethylhexyl

compound 86 R_1 = 3,7-dimethyloctyl, R_2 = 4-octylphenyl

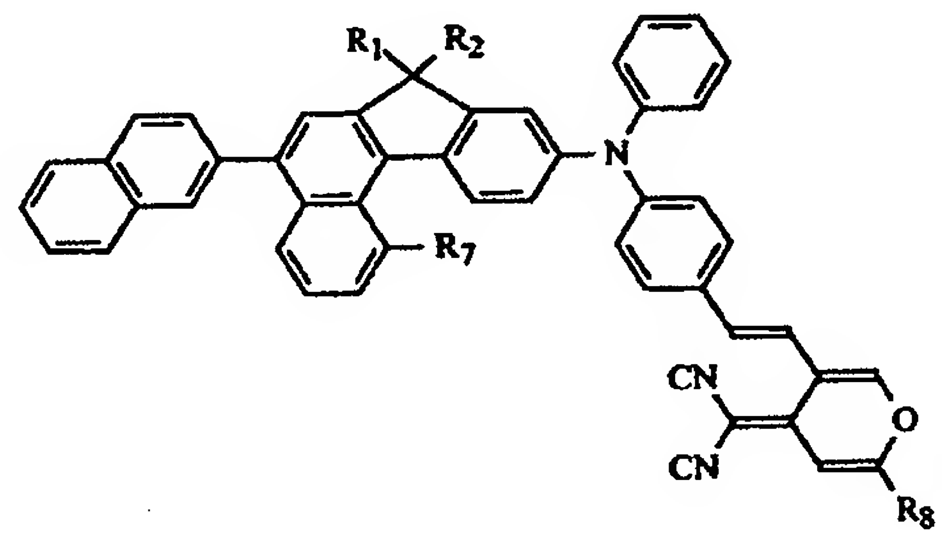
compound 87 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl



compound 88 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, $R_7 = R_8$ = n-hexyl

compound 89 R_1 = H, R_2 = 4-octylphenyl, R_7 = R_8 = 2-ethylhexyloxy

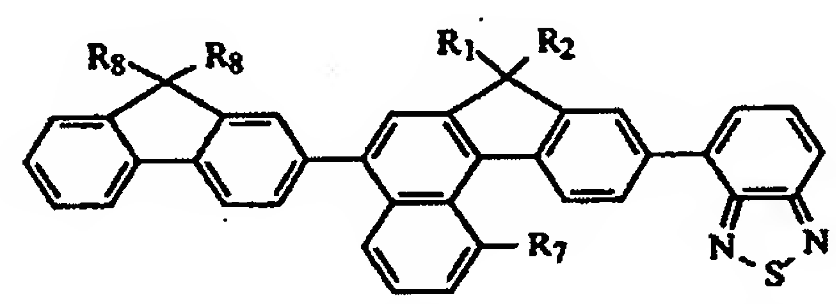
compound 90 R_1 = R_2 = 2-ethylhexyl, R_7 = 4-t-butylphenyl, R_8 = 3,7-dimethyloctyl



compound 91 R_1 = R_2 = 4-(bis(4-methylphenyl)amino)phenyl, R_7 = n-hexyl, R_8 = t-butyl

compound 92 R_1 = H, R_2 = 4-octylphenyl, R_7 = R_8 = 2-ethylhexyl

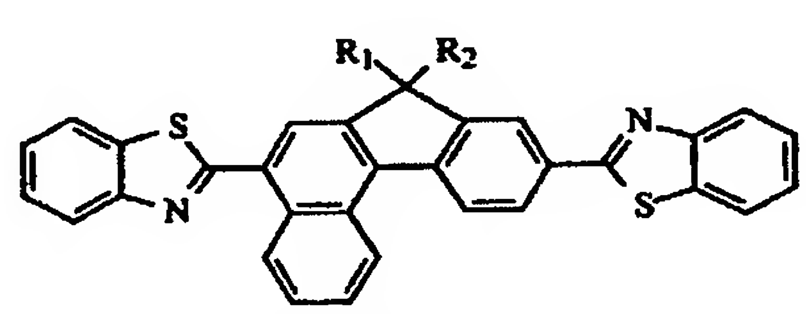
compound 93 R_1 = R_2 = 2-ethylhexyl, R_7 = 3,7-dimethyloctyloxy, R_8 = n-hexyl



compound 94 R_1 = R_2 = 4-(bis(4-methylphenyl)amino)phenyl, R_7 = n-hexyl, R_8 = phenyl

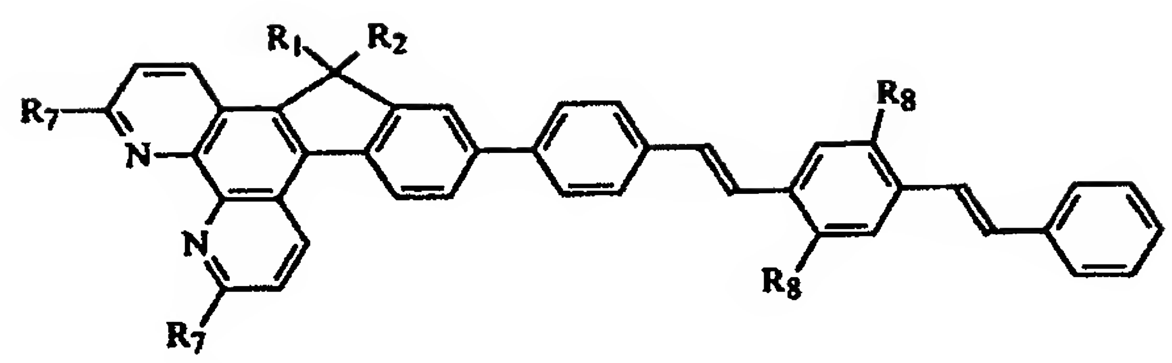
compound 95 R_1 = R_2 = 2-ethylhexyl, R_7 = 3,7-dimethyloctyloxy, R_8 = n-hexyl

compound 96 R_1 = R_2 = 2-ethylhexyl, R_7 = 3,7-dimethyloctyloxy, R_8 = n-hexyl



compound 97 R_1 = R_2 = 4-(bis(4-methylphenyl)amino)phenyl

compound 98 R_1 = ethyl = R_2

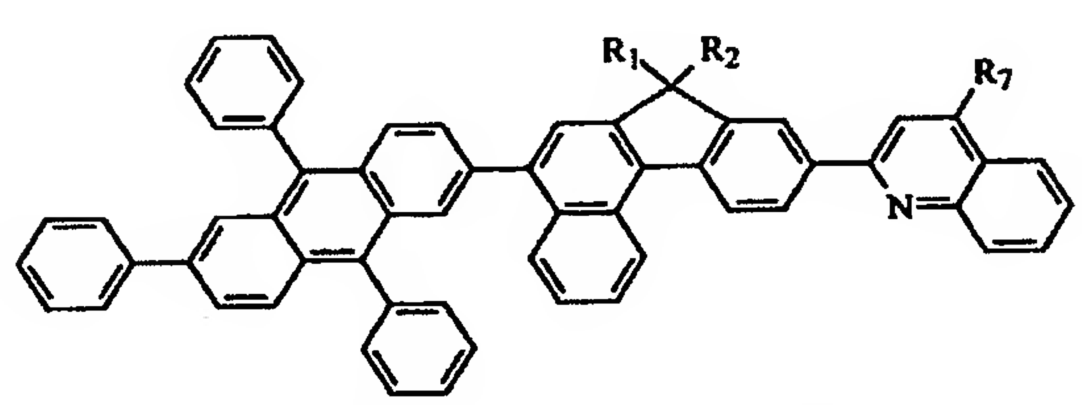


compound 99 $R_1 = R_2 = R_7 = R_8$ = 2-ethylhexyl

compound 100 R_1 = H, $R_2 = R_7$ = 4-octylphenyl, R_8 = 2-ethylhexyloxy

compound 101 $R_1 = R_2$ = 2-ethylhexyl, R_7 = t-butyl, R_8 = diphenylamino

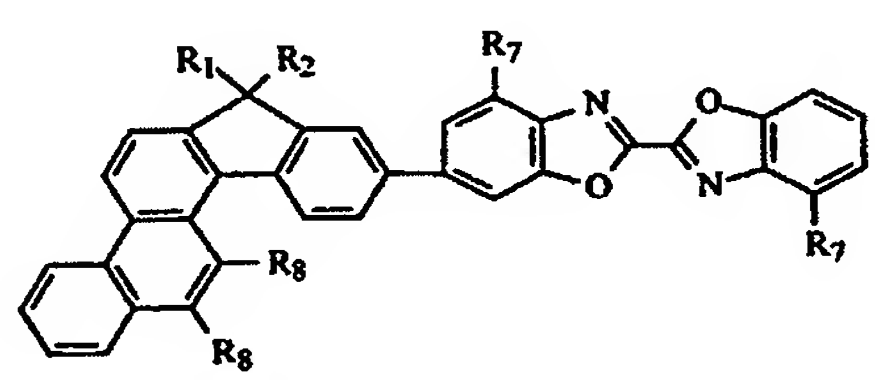
compound 102 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, R_7 = H, R_8 = phenyl



compound 103 $R_1 = R_2$ = 2-ethylhexyl, R_7 = dimethylamino

compound 104 R_1 = n-hexyl, R_2 = 4-octylphenyl, R_7 = t-butyl

compound 105 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, R_7 = H

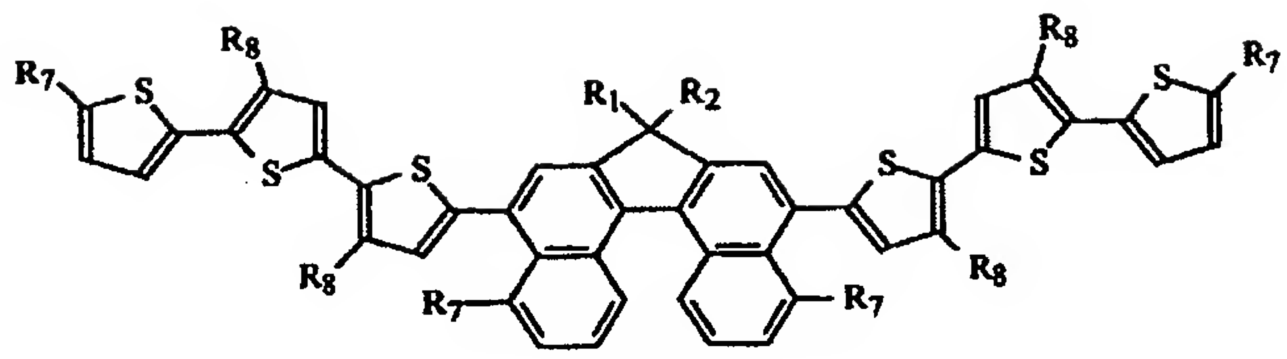


compound 106 $R_1 = R_2$ = 2-ethylhexyl, $R_7 = R_8$ = phenyl

compound 107 R_1 = H, $R_2 = R_7$ = 4-octylphenyl, R_8 = 2-ethylhexyloxy

compound 108 $R_1 = R_2$ = n-octyl, R_7 = diphenylamino, R_8 = t-butyl

compound 109 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, R_7 = t-butyl, R_8 = phenyl

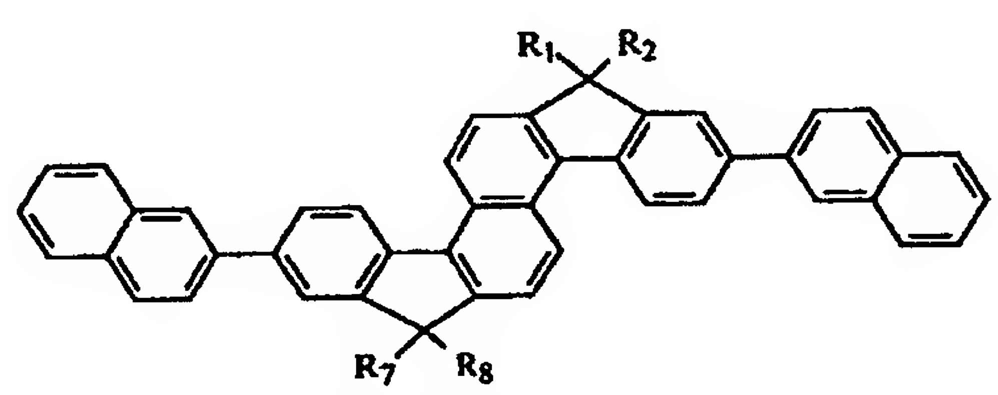


compound 110 $R_1 = R_2 = R_7 = R_8$ = 2-ethylhexyl

compound 111 $R_1 = R_2 = = R_8$ = n-hexyl, R_7 = phenyl

compound 112 $R_1 = R_7$ = n-hexyl, R_2 = (4-diphenylamino)pheny, R_8 = 2-ethylhexyl

compound 113 R_1 = H, R_2 = 4-decylphenyl, R_7 = n-hexyl, R_8 = 3,7-dimethyloctyl

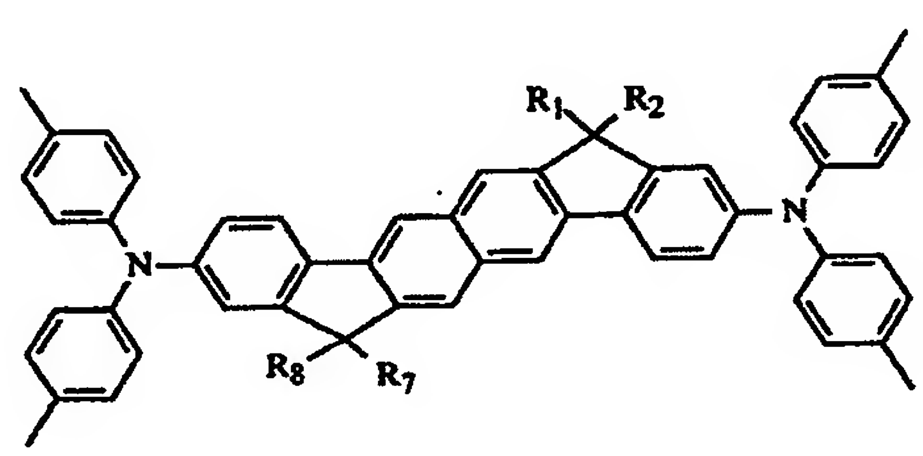


compound 114 $R_1 = R_2$ = 2-ethylhexyl, $R_7 = R_8$ = phenyl

compound 115 $R_1 = R_7$ = H, $R_2 = R_8$ = 4-octylphenyl

compound 116 $R_1 = R_2$ = n-octyl, R_7 = (4-diphenylamino)phenyl, R_8 = 2-ethylhexyl

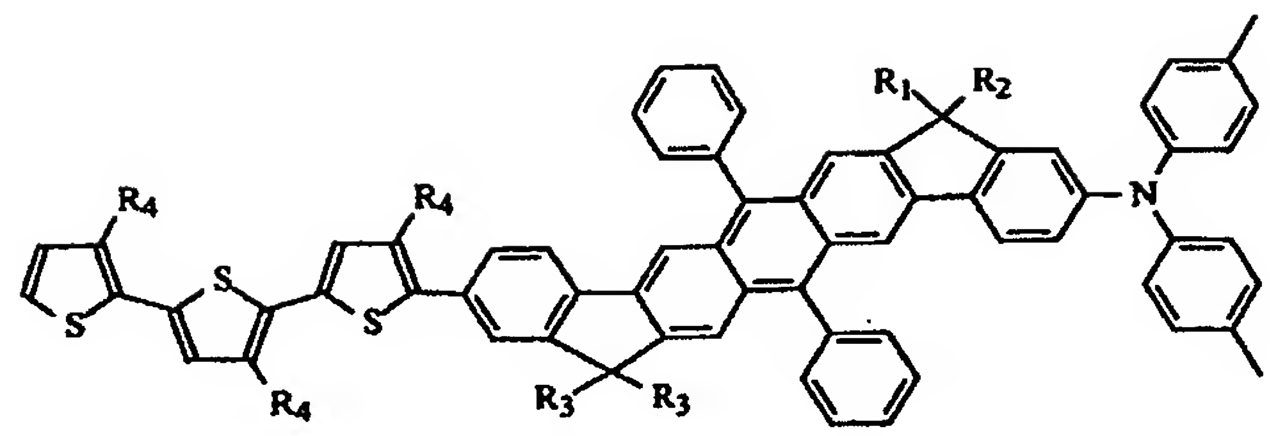
compound 117 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, R_7 = n-decyl, R_8 = 3,7-dimethyloctyl



compound 118 $R_1 = R_2 = R_7 = R_8$ = 2-ethylhexyl

compound 119 $R_1 = R_7$ = n-hexyl, $R_2 = R_8$ = 4-octylphenyl

compound 120 $R_1 = R_2$ = n-octyl, R_7 = (4-diphenylamino)phenyl, R_8 = 2-ethylhexyl

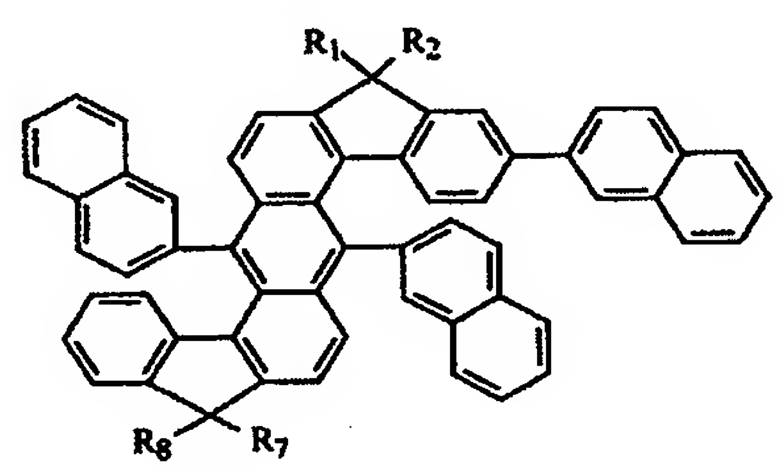


compound 121 $R_1 = R_2 = R_7 =$ 2-ethylhexyl, $R_8 =$ 4-hexylphenyl

compound 122 $R_1 = H$, $R_2 = R_7 =$ 3,7-dimethyloctyl, $R_8 =$ 2-ethylhexyl

compound 123 $R_1 = R_7 =$ (4-diphenylamino)phenyl, $R_2 =$ n-octyl, $R_8 =$ n-hexyl

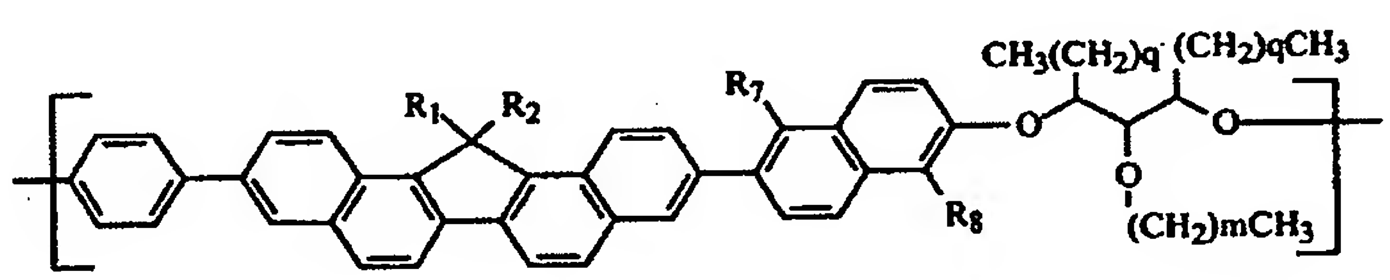
compound 124 $R_1 = R_2 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_7 =$ n-decyl, $R_8 = H$



compound 125 $R_1 = R_2 = R_7 = R_8 =$ 2-ethylhexyl

compound 126 $R_1 = H$, $R_2 = R_7 =$ 3,7-dimethyloctyl, $R_8 =$ (4-diphenylamino)phenyl

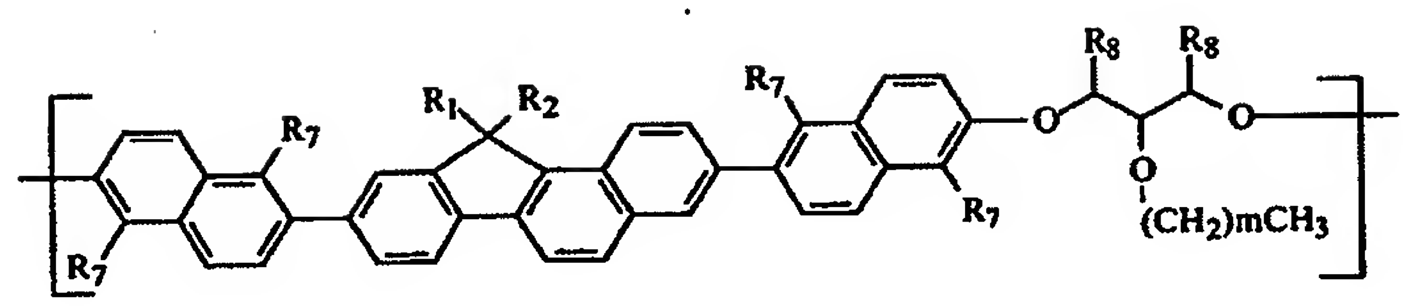
compound 127 $R_1 = R_7 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 = R_8 =$ n-decyl



compound 128 $R_1 = R_2 = R_7 = R_8 =$ 2-ethylhexyl, m = 10, q = 6

compound 129 $R_1 = H$, $R_2 =$ 4-decylphenyl, $R_7 = R_8 = =$ 3,7-dimethyloctyl, m = 2, q = 5

compound 130 $R_1 = R_7 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 = R_8 =$ n-decyl, m = q =1

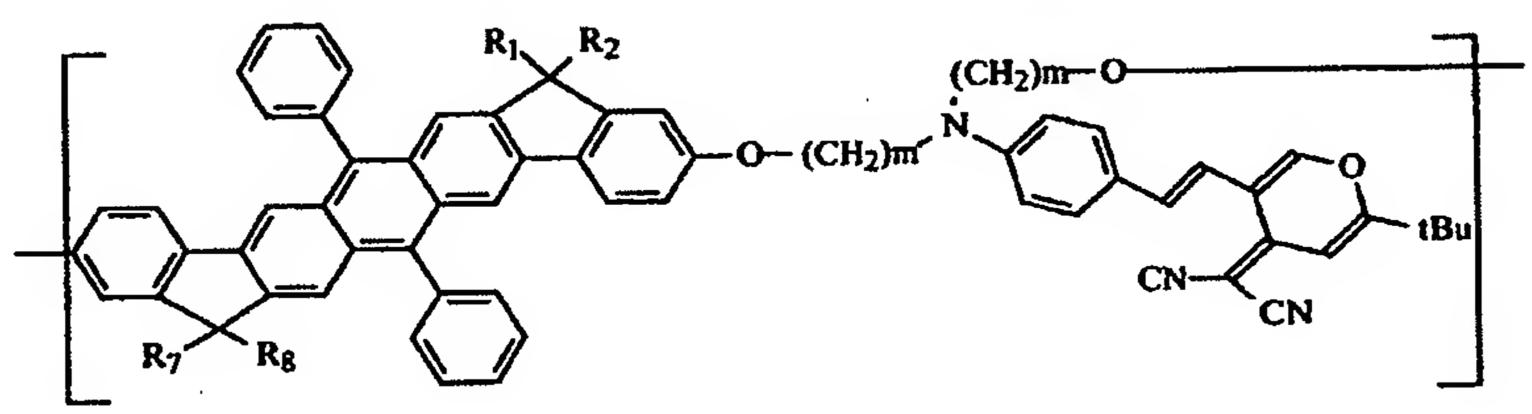


compound 131 $R_1 = R_2$ = 2-ethylhexyl, R_7 = n-hexyloxy, R_8 = ethyl, m = 10

compound 132 $R_1 = R_2$ = 4-decylphenyl, R_7 = H, R_8 = n-hexyl, m = 1

compound 133 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = H, m = 11

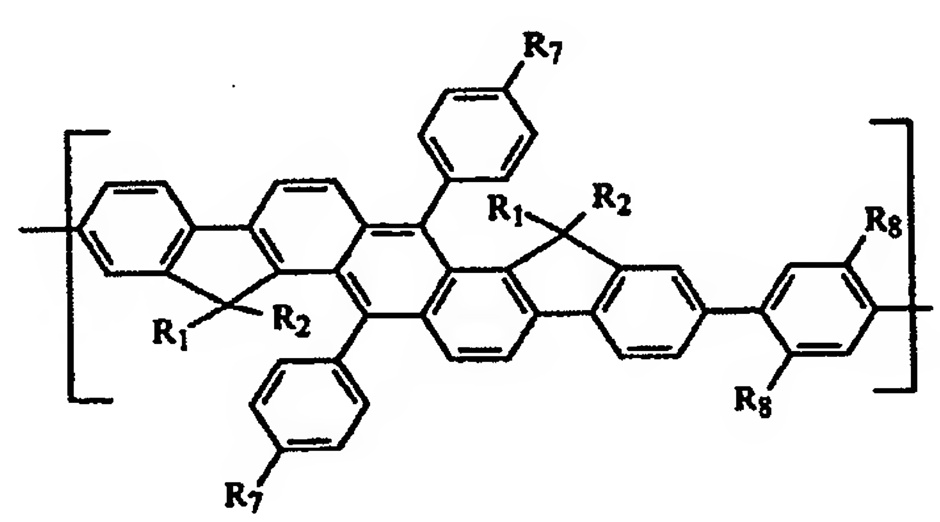
compound 134 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, R_3 = diphenylamino, R_4 = H, m = 17



compound 135 $R_1 = R_2 = R_7 = R_8$ = 2-ethylhexyl, m = 3

compound 136 R_1 = H, $R_2 = R_7$ = 3,7-dimethyloctyl, R_8 = (4-diphenylamino)phenyl, m = 2

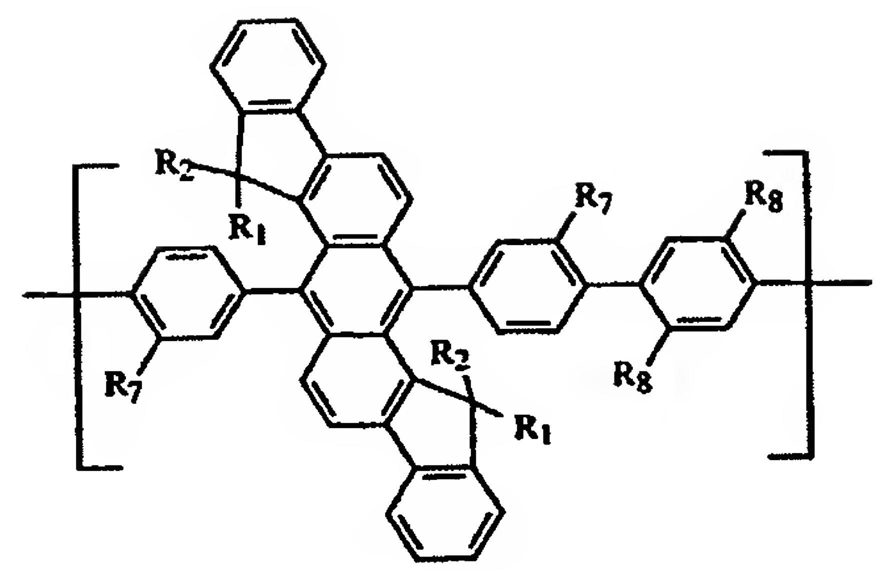
compound 137 $R_1 = R_7$ = 4-(bis(4-methylphenyl)amino)phenyl, $R_2 = R_8$ = n-decyl, m= 3



compound 137 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = 2-ethylhexyl

compound 138 R_1 = H, $R_2 = R_7$ = 3,7-dimethyloctyl, R_8 = (4-diphenylamino)phenyl

compound 139 R_1 = 4-(bis(4-methylphenyl)amino)phenyl, R_2 = n-decyl, R_7 = t-butyl, R_8 = n-hexyloxy



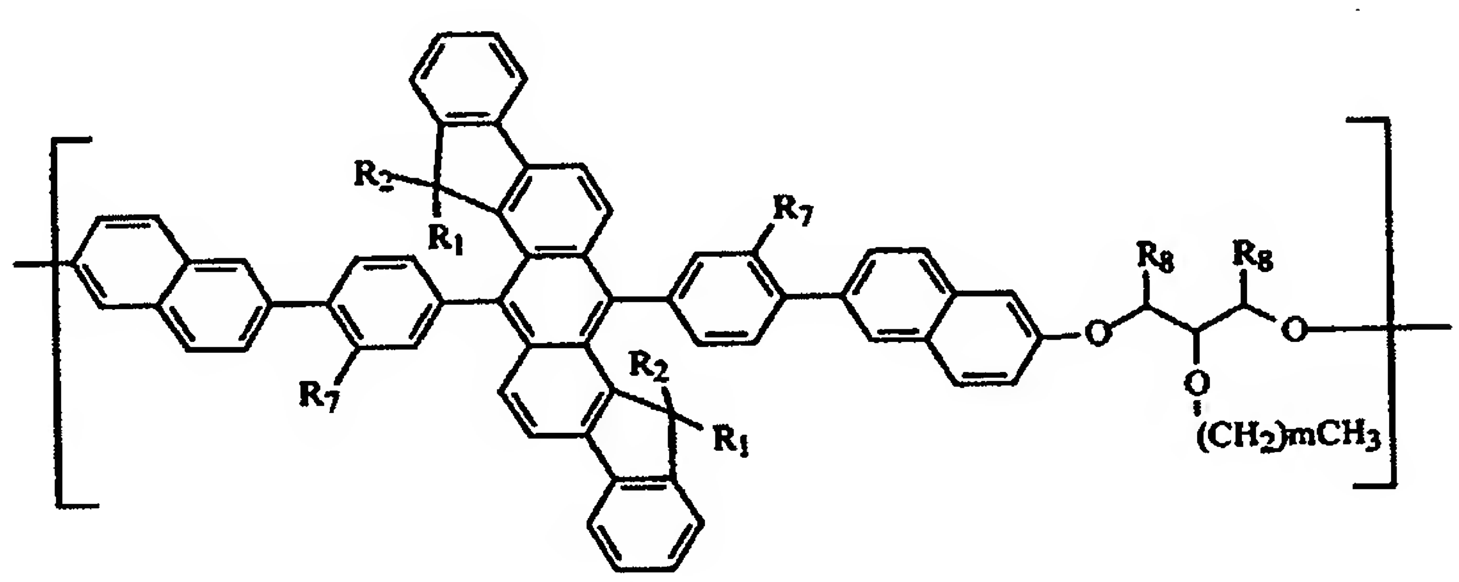
compound 140 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = 2-ethylhexyl

compound 141 R_1 = H, $R_2 = R_7$ = 3,7-dimethyloctyl, R_8 = (4-diphenylamino)phenyl

compound 142 R_1 = 4-(bis(4-methylphenyl)amino)phenyl, R_2 = n-decyl, R_7 = t-butyl, R_8 = n-hexyloxy

compound 143 R_1 = 4-(N-carbazole)phenyl, R_2 = n-decyl, R_7 = 2-ethylhexyloxy, R_8 = n-hexyl

compound 144 R_1 = 4-(n-decyl)phenyl, $R_2 = R_7 = R_8$ = H

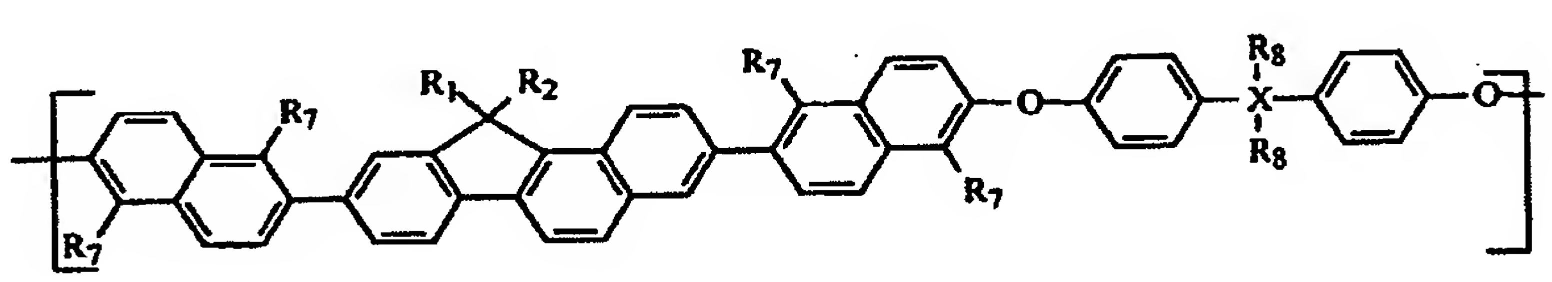


compound 145 $R_1 = R_2$ = 2-ethylhexyl, R_7 = n-hexyloxy, R_8 = ethyl, m = 10

compound 146 $R_1 = R_2$ = 4-decylphenyl, R_7 = H, R_8 = n-hexyl, m = 1

compound 147 $R_1 = R_7 = R_8$ = H, R_2 = 4-decylphenyl, m = 11

compound 148 $R_1 = R_2$ = 4-(bis(4-methylphenyl)amino)phenyl, R_7 = diphenylamino, R_8 = H, m = 17

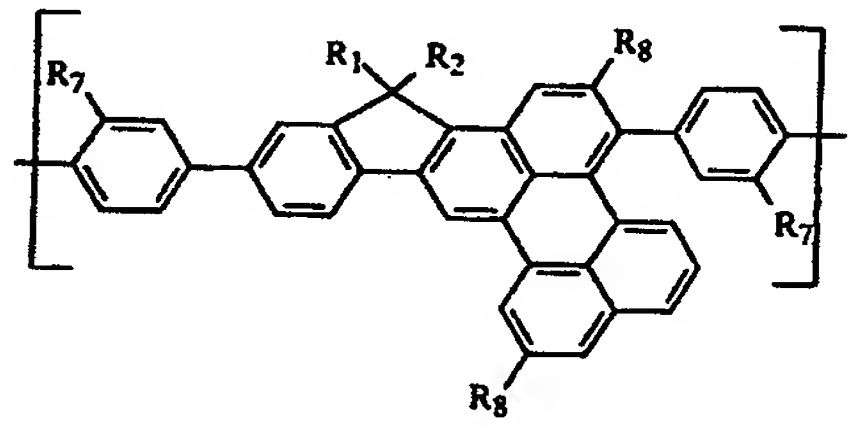


compound 149 $R_1 = R_2 =$ 2-ethylhexyl, $R_7 =$ n-hexyloxy, $R_8 =$ ethyl, X = C

compound 150 $R_1 = R_2 =$ 2-ethylhexyl, $R_7 =$ n-hexyl, $R_8 = CF_3$, X = C

compound 151 $R_1 = R_7 =$ 4-decylphenyl, $R_2 =$ H, $R_8 =$ n-butyl, X = Si

compound 152 $R_1 =$ H, $R_2 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_7 =$ diphenylamino, $R_8 =$ n-hexyl, X = Si

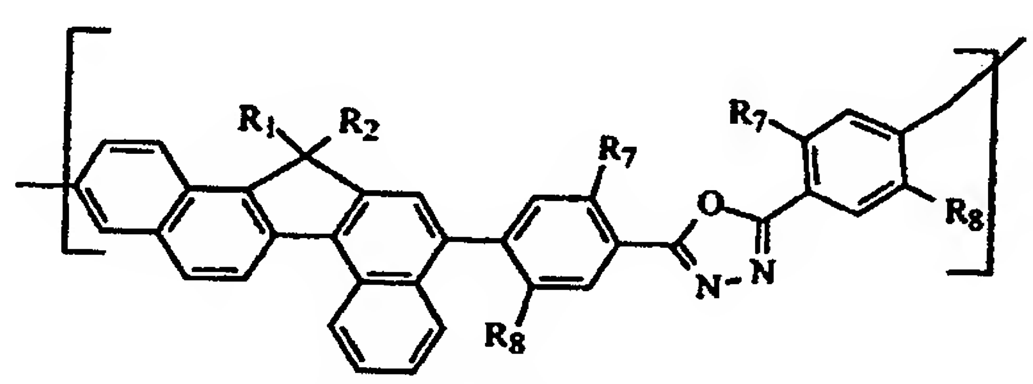


compound 153 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ 2-ethylhexyl

compound 154 $R_1 =$ H, $R_2 = R_7 =$ 3,7-dimethyloctyl, $R_8 =$ (4-diphenylamino)phenyl

compound 155 $R_1 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 =$ n-decyl, $R_7 =$ t-butyl, $R_8 =$ n-hexyloxy

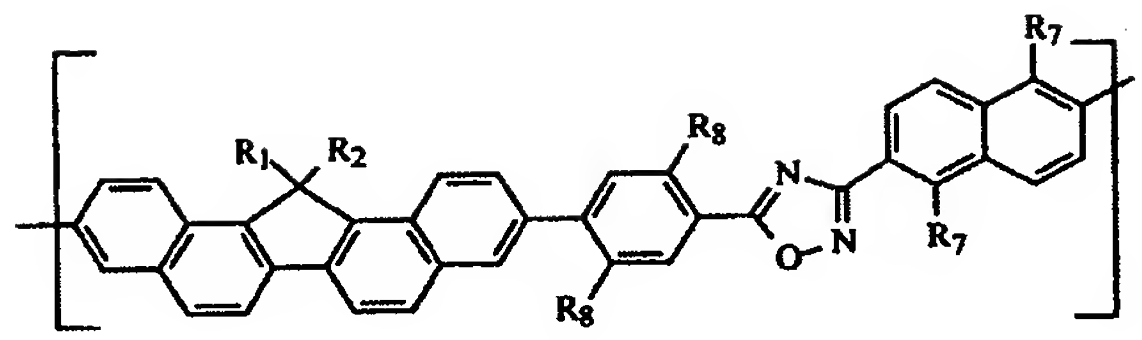
compound 156 $R_1 =$ 4-(N-carbazole)phenyl, $R_2 =$ n-decyl, $R_7 =$ 2-ethylhexyloxy, $R_8 =$ n-hexyl



compound 157 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ 2-ethylhexyloxy

compound 158 $R_1 =$ H, $R_2 = R_7 =$ 3,7-dimethyloctyl, $R_8 =$ (4-diphenylamino)phenyl

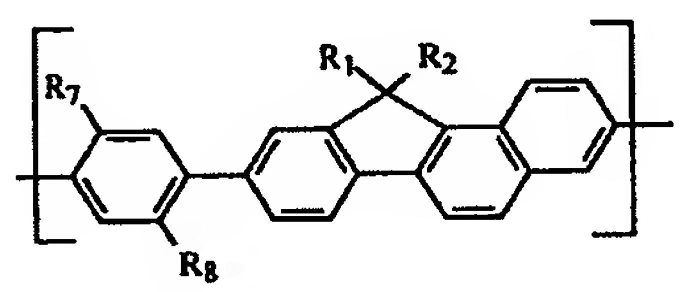
compound 159 $R_1 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 =$ n-decyl, $R_7 =$ t-butyl, $R_8 =$ n-hexyloxy



compound 160 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = 2-ethylhexyloxy

compound 161 R_1 = H, $R_2 = R_7$ = 3,7-dimethyloctyl, R_8 = (4-diphenylamino)phenyl

compound 162 R_1 = 4-(bis(4-methylphenyl)amino)phenyl, R_2 = n-decyl, R_7 = t-butyl, R_8 = n-hexyloxy



compound 163 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = 2-ethylhexyloxy

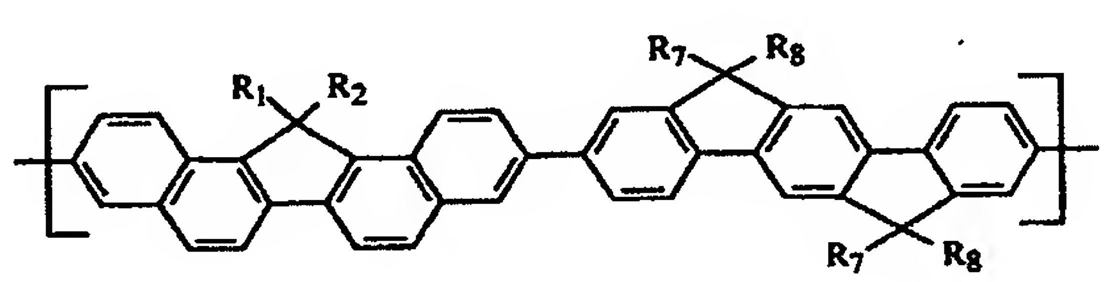
compound 164 R_1 = n-hexyl, $R_2 = R_7$ = 3,7-dimethyloctyl, R_8 = (4-diphenylamino)phenyl

compound 165 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = H

compound 166 R_1 = 4-(bis(4-methylphenyl)amino)phenyl, R_2 = n-decyl, R_7 = t-butyl, R_8 = n-hexyloxy

compound 167 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = n-octyl

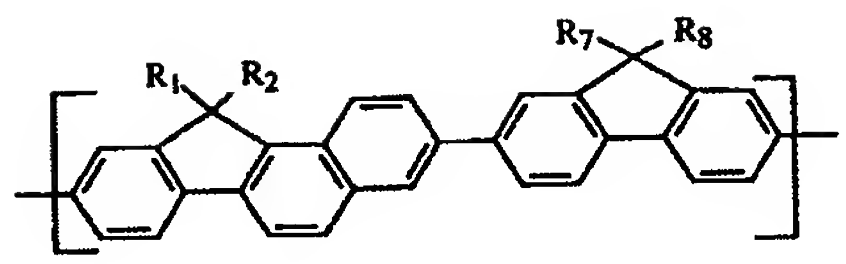
compound 168 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = n-hexyloxy



compound 169 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = 2-ethylhexyl

compound 170 R_1 = H, $R_2 = R_7$ = 3,7-dimethyloctyl, R_8 = (4-diphenylamino)phenyl

compound 171 R_1 = 4-(bis(4-methylphenyl)amino)phenyl, R_2 = n-decyl, $R_7 = R_8$ = n-hexyl

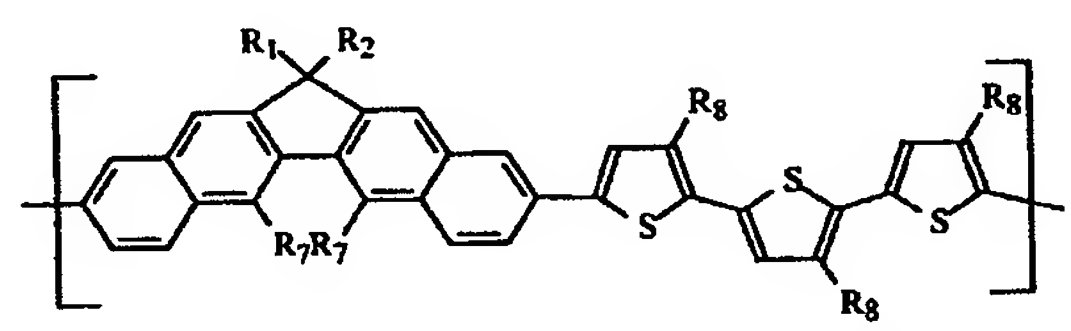


compound 172 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ 4-octylphenyl

compound 173 $R_1 =$ n-hexyl, $R_2 = R_7 =$ 3,7-dimethyloctyl, $R_8 =$ (4-diphenylamino)phenyl

compound 174 $R_1 = R_2 = R_7 = R_8 =$ n-hexyl

compound 175 $R_1 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 =$ n-decyl, $R_7 = R_8$ = n-octyl

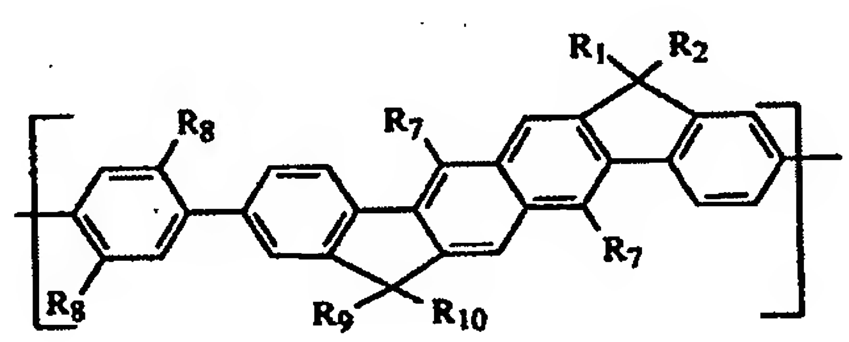


compound 176 $R_1 = R_2 =$ n-hexyl, $R_7 =$ n-hexyloxy, $R_8 =$ 2-ethylhexyl

compound 177 $R_1 = R_7 =$ n-hexyl, $R_2 =$ 3,7-dimethyloctyl, $R_8 =$ (4-diphenylamino)phenyl

compound 178 $R_1 = R_2 = R_7 = R_8 =$ n-hexyl

compound 179 $R_1 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 =$ n-decyl, $R_7 =$ methyl, $R_8 =$ n-hexyl



compound 180 $R_1 = R_2 = R_9 = R_{10} =$ n-hexyl, $R_7 = R_8 =$ 2-ethylhexyloxy

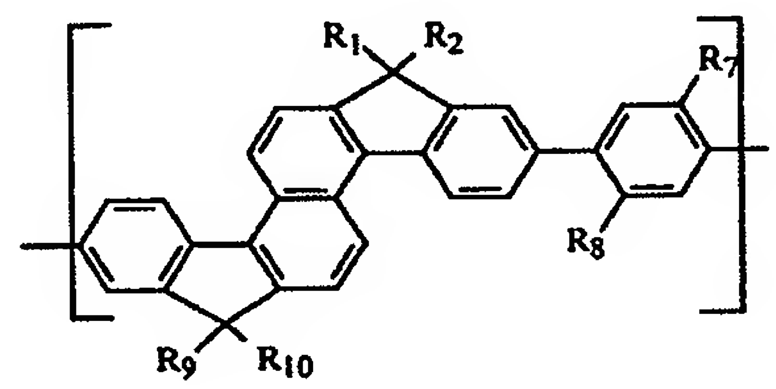
compound 181 $R_1 = R_9 =$ n-hexyl, $R_2 = R_7 = R_{10} =$ 3,7-dimethyloctyl, $R_8 =$ (4-diphenylamino)phenyl

compound 182 $R_1 = R_2 = R_9 = R_{10} =$ n-hexyl, $R_7 =$ n-hexyloxy, $R_8 =$ H

compound 183 $R_1 = R_9 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 = = R_{10} =$ n-decyl, $R_7 =$ t-butyl, $R_8 =$ n-hexyloxy

compound 184 $R_1 = R_2 = R_9 = R_{10} =$ n-hexyl, $R_7 =$ n-hexyloxy, $R_8 =$ n-octyl

compound 185 $R_1 = R_2 = R_9 = R_{10} =$ n-hexyl, $R_7 = R_8 =$ n-hexyloxy

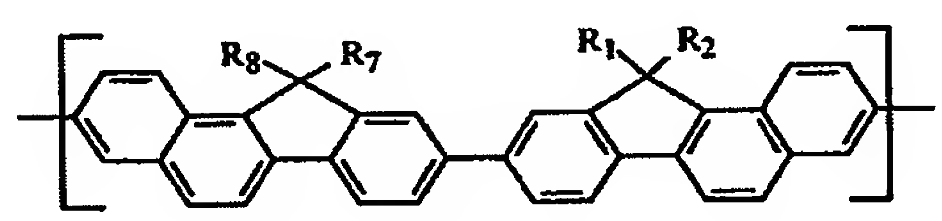


compound 186 $R_1 = R_2 = R_9 = R_{10} =$ n-hexyl, $R_7 =$ n-hexyloxy, $R_8 =$ H

compound 187 $R_1 = R_2 = R_9 = R_{10} =$ n-hexyl, $R_7 = R_8 =$ (4-diphenylamino)phenyl

compound 188 $R_1 = R_2 = R_7 = R_8 = = R_9 = R_{10} =$ n-hexyl

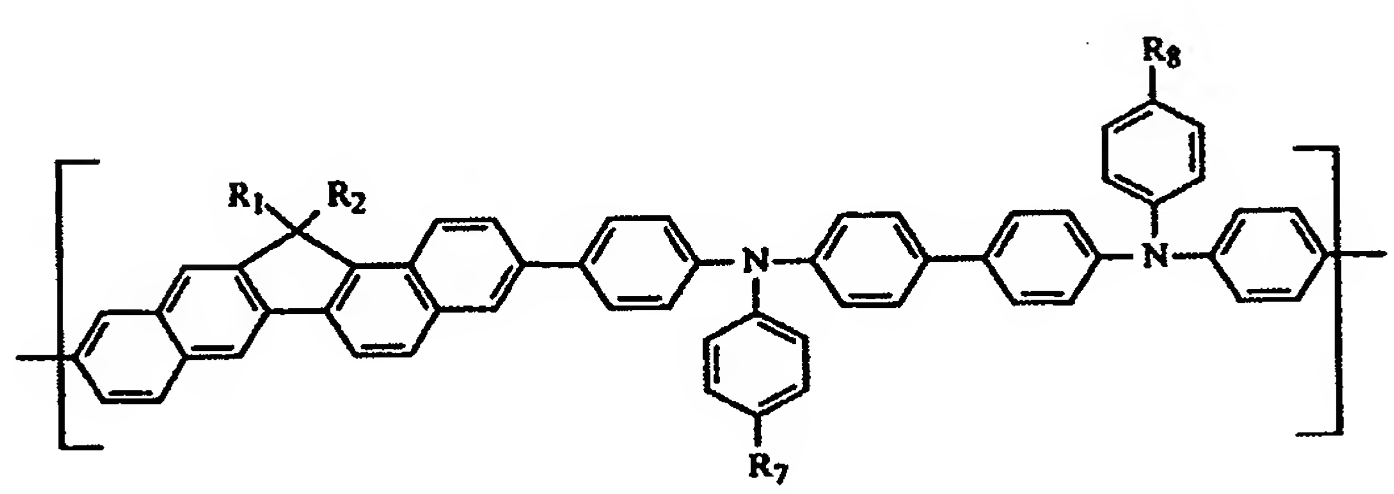
compound 189 $R_1 = R_9 =$ 4-decylphenyl, $R_2 = R_{10} =$ H, $R_7 = R_8 =$ n-hexyloxy



compound 190 $R_1 = R_2 = R_7 = R_8 =$ n-hexyl

compound 191 $R_1 =$ H, $R_2 = R_7 =$ 3,7-dimethyloctyl, $R_8 =$ (4-diphenylamino)phenyl

compound 192 $R_1 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 =$ n-decyl, $R_7 = R_8 =$ n-hexyl

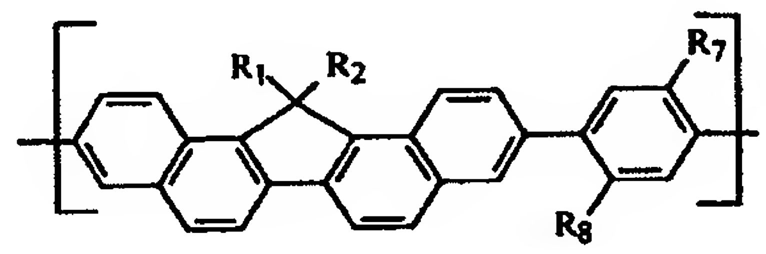


compound 193 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ n-butyl

compound 194 $R_1 = R_2 =$ 2-ethylhexyl, $R_7 = R_8 =$ (4-diphenylamino)phenyl

compound 195 $R_1 = R_2 = R_7 = R_8 =$ n-hexyl

compound 196 $R_1 =$ 4-decylphenyl, $R_2 =$ H, $R_7 = R_8 = CF_3$



compound 197 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ 2-ethylhexyloxy

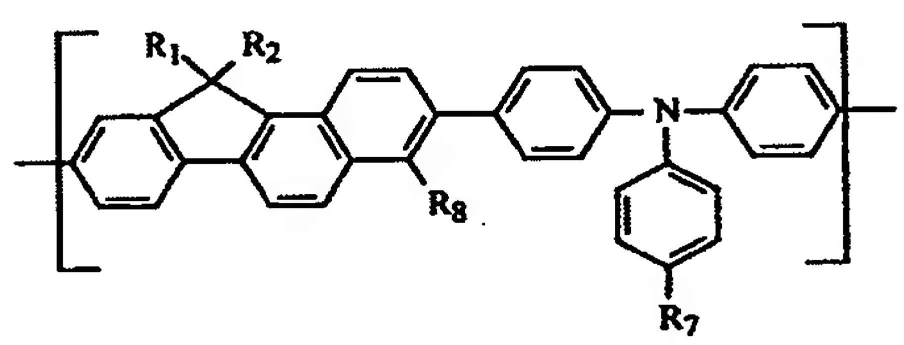
compound 198 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ H

compound 199 $R_1 =$ 2-ethylhexyl, $R_2 =$ n-hexyl, $R_7 = R_8 =$ H

compound 200 $R_1 =$ n-hexyl, $R_2 = R_7 =$ 3,7-dimethyloctyl, $R_8 =$ (4-diphenylamino)phenyl

compound 201 $R_1 =$ 2-ethylhexyl, $R_2 =$ n-hexyl, $R_7 = R_8 =$ n-hexyloxy

compound 202 $R_1 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 =$ n-decyl, $R_7 =$ t-butyl, $R_8 =$ n-hexyloxy



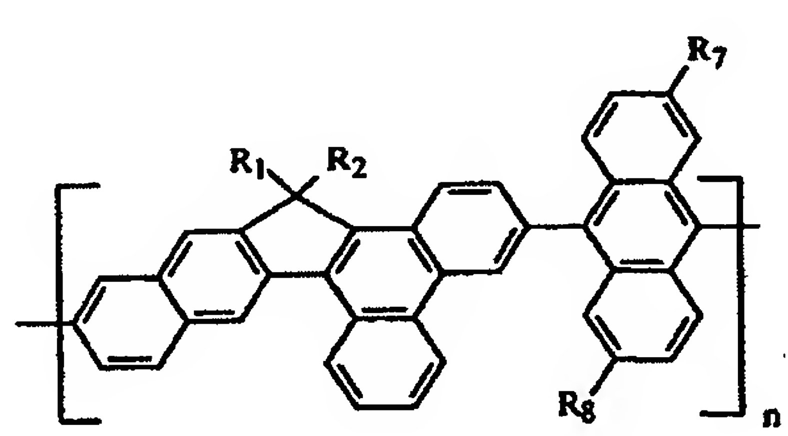
compound 203 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ 2-ethylhexyl

compound 204 $R_1 =$ 2-ethylhexyl, $R_2 =$ n-hexyl, $R_7 = R_8 =$ H

compound 205 $R_1 =$ n-hexyl, $R_2 = R_8 =$ 3,7-dimethyloctyl, $R_7 =$ (4-diphenylamino)phenyl

compound 206 $R_1 = R_2 =$ n-hexyl, $R_7 =$ t-butyl, $R_8 =$ H

compound 207 $R_1 =$ 4-(bis(4-methylphenyl)amino)phenyl, $R_2 =$ n-decyl, $R_7 =$ n-butyl, $R_8 =$ n-hexyloxy

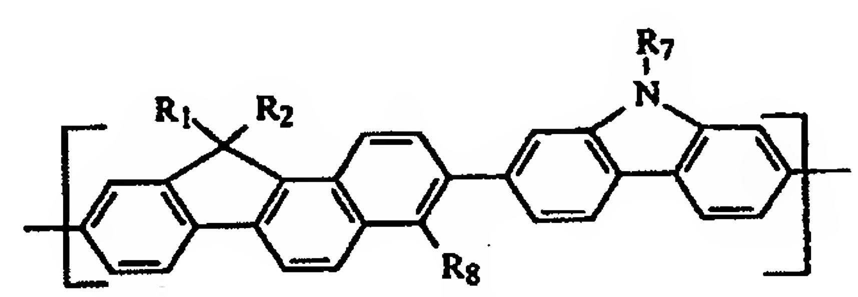


compound 208 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = 2-ethylhexyloxy

compound 209 R_1 = 2-ethylhexyl, R_2 = n-hexyl, $R_7 = R_8$ = n-butyl

compound 210 R_1 = n-hexyl, R_2 = (4-diphenylamino)phenyl, R_7 = H, R_8 = 3,7-dimethyloctyl

compound 211 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = 4-(bis(4-methylphenyl)amino)phenyl

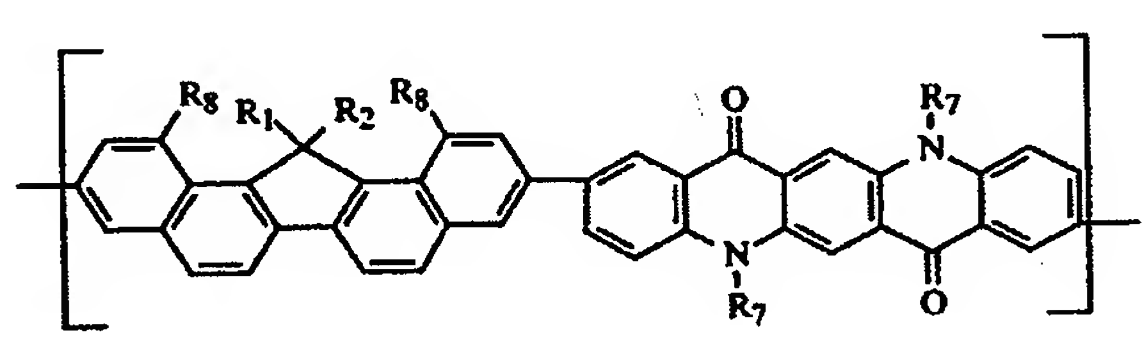


compound 212 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = 2-ethylhexyl

compound 213 R_1 = 2-ethylhexyl, R_2 = n-hexyl, R_7 = 4-t-butylphenyl, R_8 = H

compound 214 R_1 = n-hexyl, $R_2 = R_8$ = 3,7-dimethyloctyl, R_7 = (4-diphenylamino)phenyl

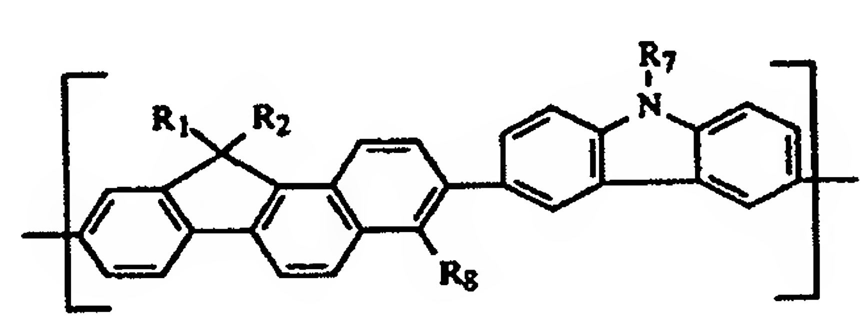
compound 215 $R_1 = R_2$ = n-hexyl, R_7 = 2-ethylhexyl, R_8 = H



compound 216 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = 2-ethylhexyl

compound 217 R_1 = 2-ethylhexyl, R_2 = n-hexyl, R_7 = 4-t-butylphenyl, R_8 = H

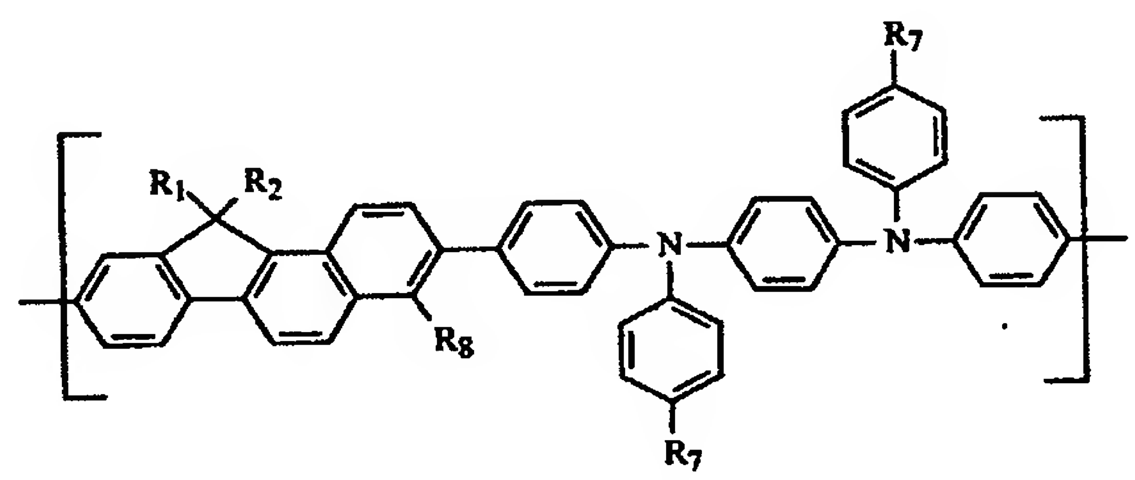
compound 218 R_1 = n-hexyl, R_2 = 3,7-dimethyloctyl, R_7 = (4-diphenylamino)pheny, R_8 = n-hexyloxy



compound 219 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = 2-ethylhexyl

compound 220 R_1 = 2-ethylhexyl, R_2 = n-hexyl, R_7 = 4-t-butylphenyl, R_8 = n-hexyloxy

compound 221 R_1 = R_2 = n-hexyl, R_7 = 2-ethylhexyl, R_8 = H

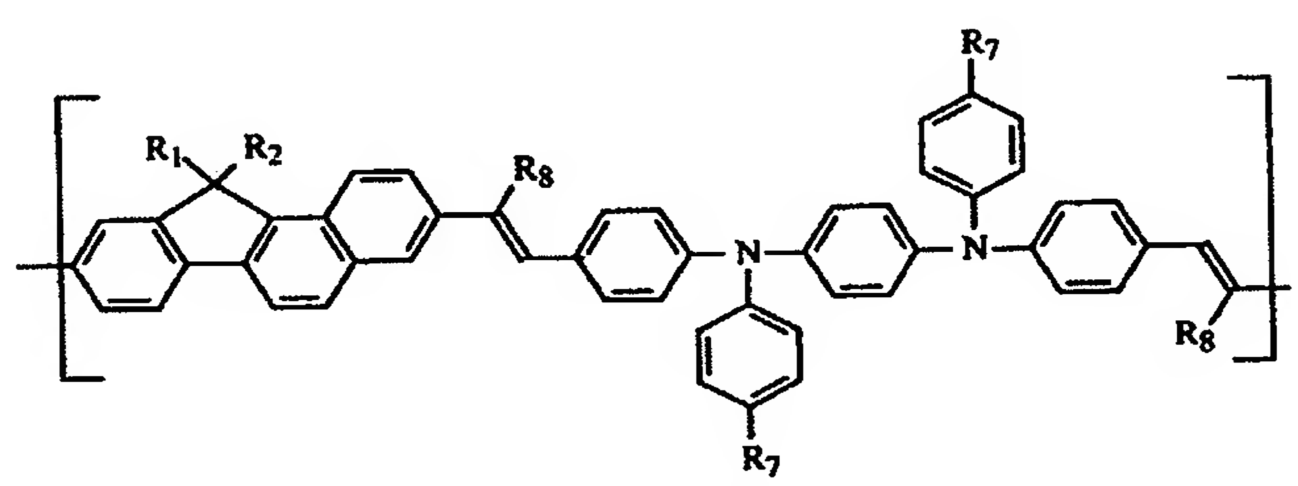


compound 222 R_1 = R_2 = n-hexyl, R_7 = R_8 = n-butyl

compound 223 R_1 = R_2 = 2-ethylhexyl, R_7 = R_8 = (4-diphenylamino)phenyl

compound 224 R_1 = R_2 = R_7 = R_8 = n-hexyl

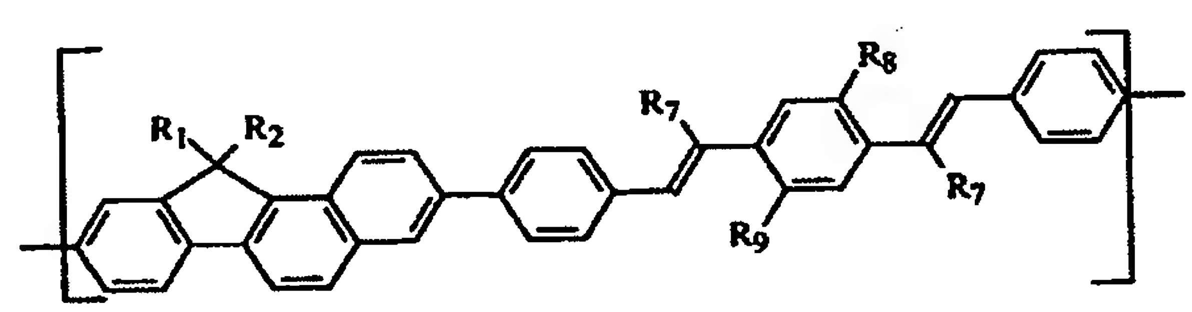
compound 225 R_1 = 4-decylphenyl, R_2 = H, R_7 = R_8 = CF_3



compound 226 R_1 = R_2 = n-hexyl, R_7 = n-butyl, R_8 = H

compound 227 R_1 = R_2 = 2-ethylhexyl, R_7 = 4-t-butylphenyl, R_8 = CN

compound 228 R_1 = 4-decylphenyl, R_2 = H, R_7 = CF_3, R_8 = phenyl

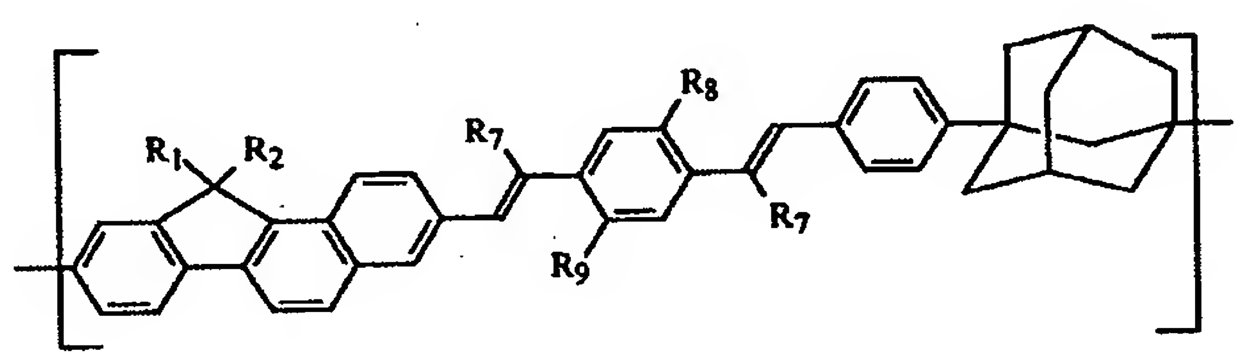


compound 229 R_1 = R_2 = n-hexyl, R_7 = phenyl, R_8 = R_9 = 2-ethylhexyl

compound 230 R_1 = 2-ethylhexyl, R_2 = n-hexyl, R_7 = R_8 = H, R_9 = 4-t-butylphenyl

compound 231 $R_1 = R_2$ = n-hexyl, R_7 = H, R_8 = methoxy, R_9 = 3,7-dimethyloctyloxy

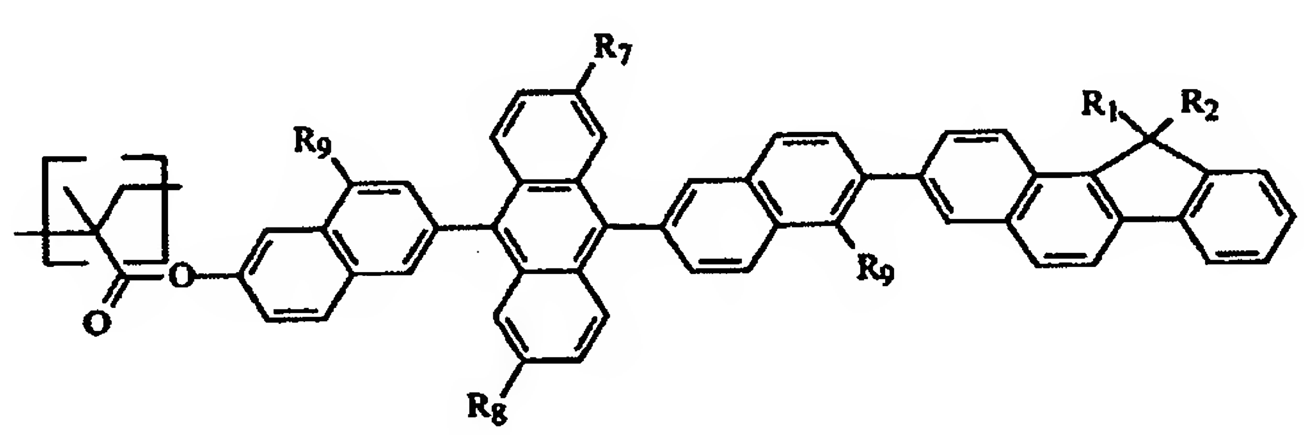
compound 232 R_1 = n-hexyl, $R_2 = R_8$ = 3,7-dimethyloctyl, R_7 = H, R_9 = (4-diphenylamino)phenyl



compound 233 R_1 = 2-ethylhexyl, R_2 = n-hexyl, R_7 = CN, $R_8 = R_9$ = 4-t-butylphenyl

compound 234 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = H, R_9 = 2-ethylhexyl

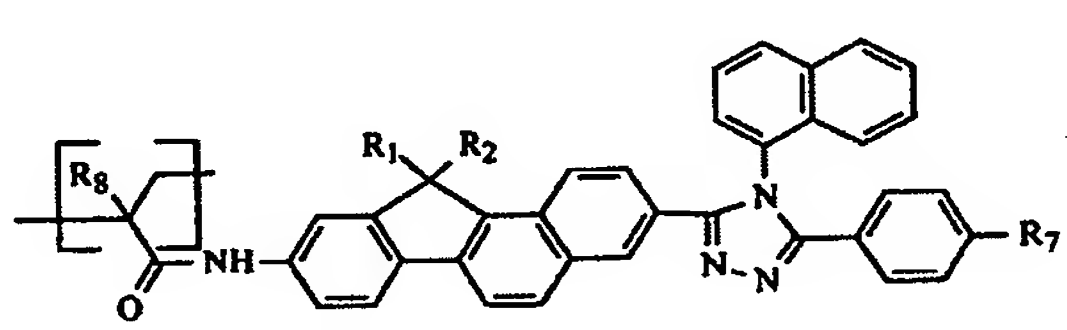
compound 235 R_1 = 4-decylphenyl, $R_2 = R_8$ = 3,7-dimethyloctyl, R_7 = H, R_9 = (4-diphenylamino)phenyl



compound 236 R_1 = 2-ethylhexyl, R_2 = n-hexyl, R_7 = CN, $R_8 = R_9$ = 4-t-butylphenyl

compound 237 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = H, R_9 = 2-ethylhexyl

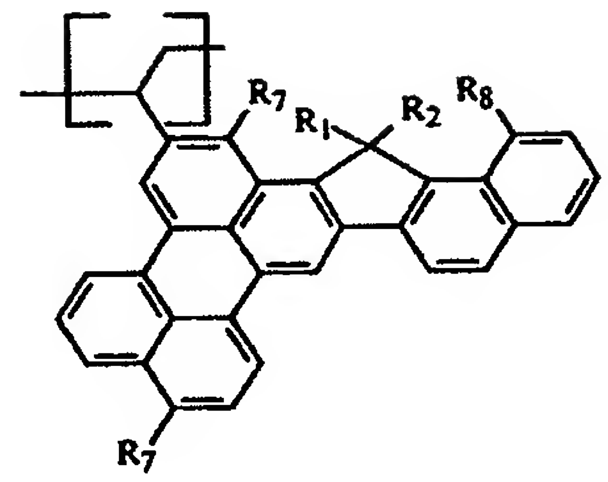
compound 238 R_1 = 4-decylphenyl, $R_2 = R_8$ = 3,7-dimethyloctyl, R_7 = H, R_9 = (4-diphenylamino)phenyl



compound 239 R_1 = 2-ethylhexyl, R_2 = n-hexyl, R_7 = t-butyl, R_8 = H

compound 240 $R_1 = R_2$ = n-hexyl, R_7 = phenyl, R_8 = CN

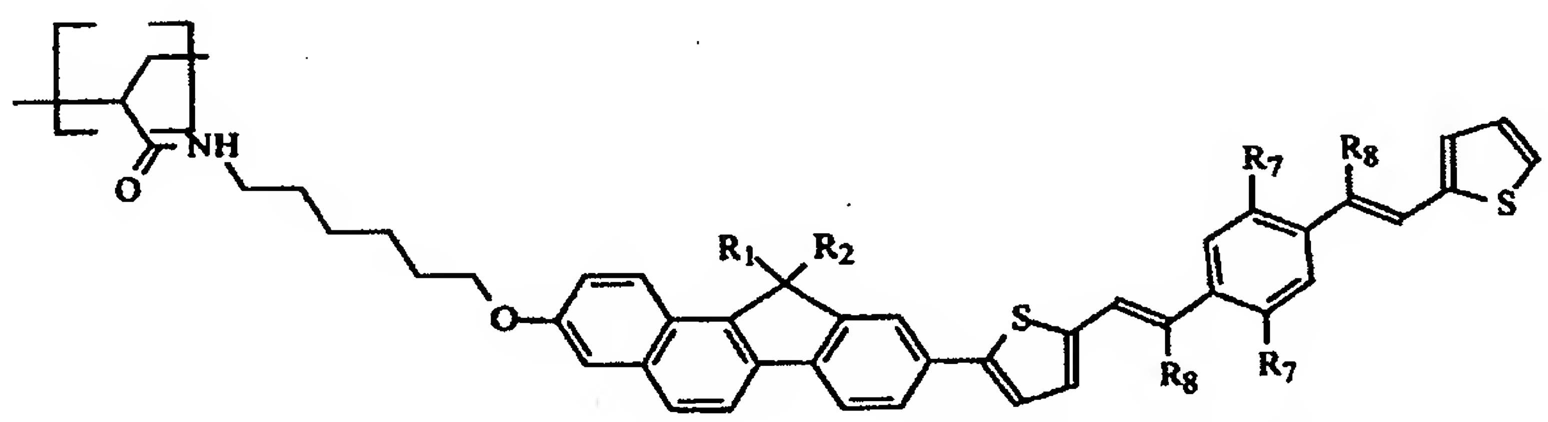
compound 241 R_1 = 4-decylphenyl, $R_2 = R_7$ = 3,7-dimethyloctyl, R_8 = methyl



compound 242 $R_1 = R_2 = R_7 = R_8$ = 2-ethylhexyl

compound 243 $R_1 = R_2$ = n-hexyl, R_7 = 4-decylphenyl, R_8 = 2-ethylhexyloxy

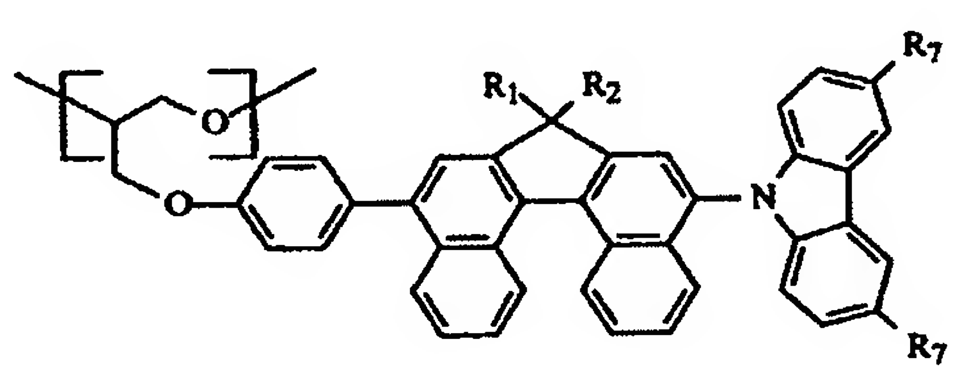
compound 244 R_1 = (4-diaminophenyl)lphenyl, $R_2 = R_7$ = 3,7-dimethyloctyl, R_8 = H



compound 245 R_1 = 2-ethylhexyl, R_2 = n-hexyl, R_7 = t-butyl, R_8 = H

compound 246 $R_1 = R_2$ = n-hexyl, R_7 = n-octyloxy, R_8 = CN

compound 247 R_1 = 4-decylphenyl, $R_2 = R_7$ = 3,7-dimethyloctyl, R_8 = CN

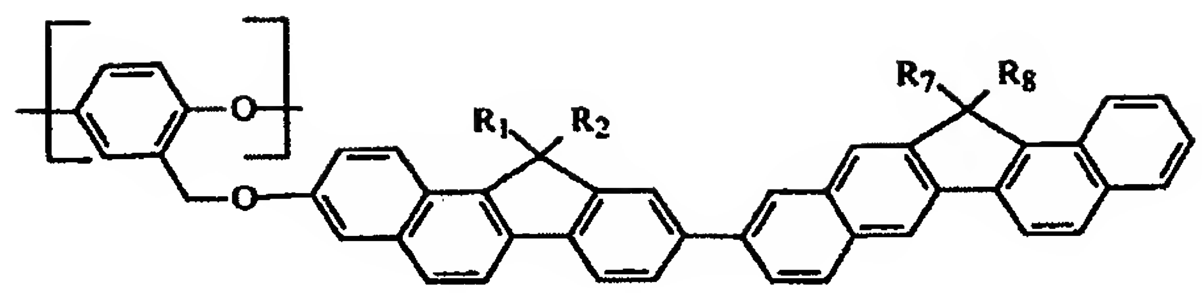


compound 248 R_1 = 2-ethylhexyl, R_2 = n-hexyl, R_7 = t-butyl

compound 249 $R_1 = R_2$ = n-hexyl, R_7 = phenyl

compound 250 R_1 = 4-decylphenyl, R_2 = n-octyl, R_7 = CN

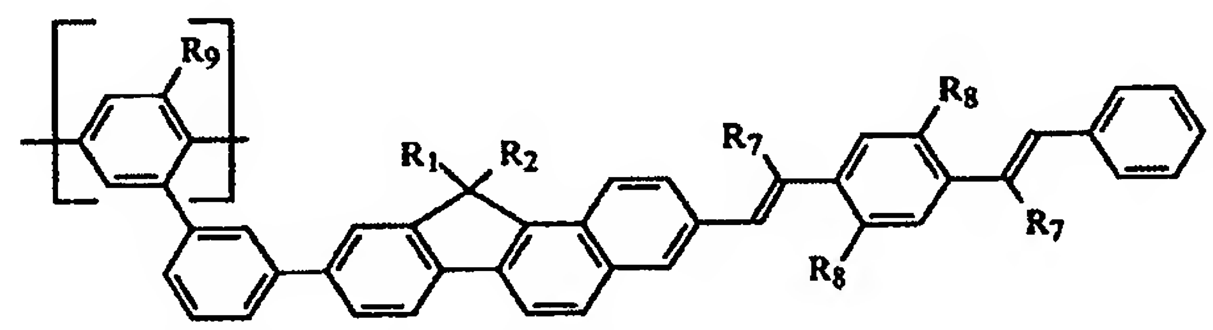
compound 251 R_1 = 4-(diphenylamino)phenyl, R_2 = n-hexyl, R_7 = n-hexyloxy



compound 252 $R_1 = R_2 =$ 2-ethylhexyl, $R_7 = R_8 =$ 4-t-butylphenyl

compound 253 $R_1 = R_2 = R_7 = R_8 =$ n-octyl

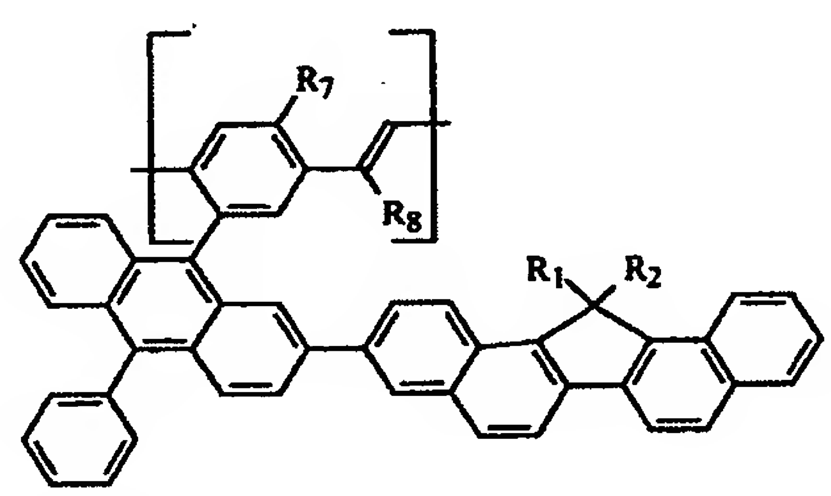
compound 254 $R_1 = R_7 =$ 4-decylphenyl, $R_2 = R_8 =$ 3,7-dimethyloctyl



compound 255 $R_1 =$ 2-ethylhexyl, $R_2 =$ n-hexyl, $R_7 =$ CN, $R_8 = R_9 =$ 4-t-butylphenyl

compound 256 $R_1 = R_2 =$ n-hexyl, $R_7 =$ H, $R_8 =$ n-hexyloxy, $R_9 =$ 2-ethylhexyl

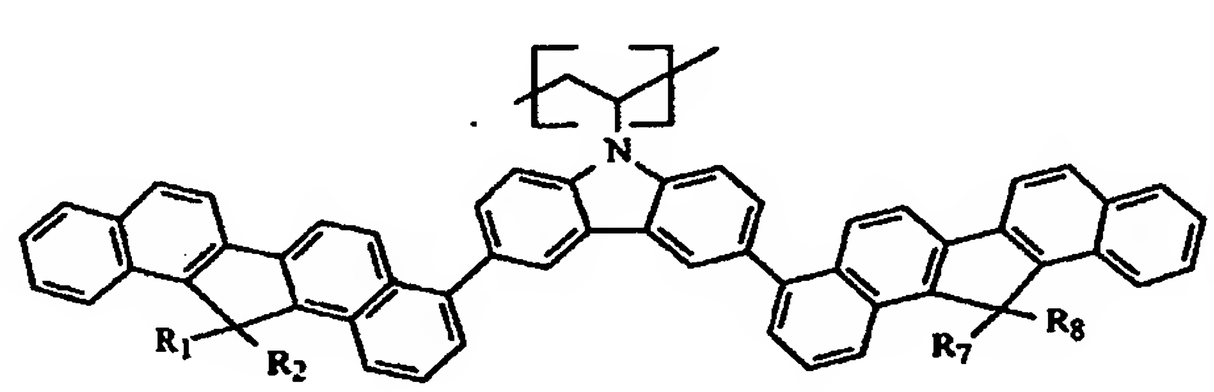
compound 257 $R_1 =$ 4-decylphenyl, $R_2 = R_8 =$ 3,7-dimethyloctyl, $R_7 =$ H, $R_9 =$ (4-diphenylamino)phenyl



compound 258 $R_1 =$ 2-ethylhexyl, $R_2 =$ n-hexyl, $R_7 =$ n-hexyl, $R_8 =$ H

compound 259 $R_1 = R_2 =$ n-hexyl, $R_7 =$ n-octyloxy, $R_8 =$ CN

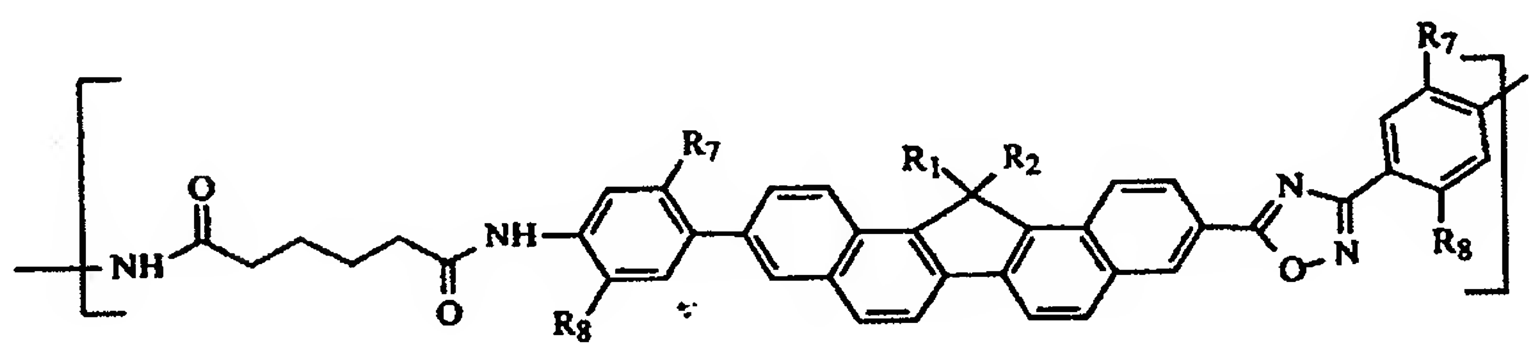
compound 260 $R_1 = R_7 =$ 4-decylphenyl, $R_2 =$ 3,7-dimethyloctyl, $R_8 =$ CN



compound 261 $R_1 = R_2 = R_7 = R_8$ = 2-ethylhexyl

compound 262 $R_1 = R_7$ = n-hexyl, $R_2 = R_8$ = (4-diphenylamino)phenyl

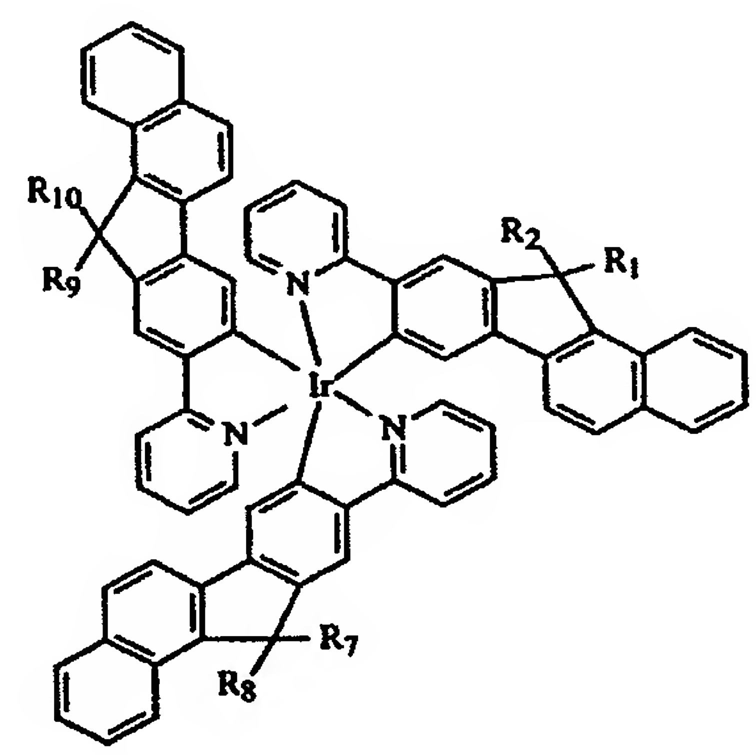
compound 263 R_1 = n-hexyl, R_2 = (4-diphenylamino)phenyl, R_7 = H, R_8 = 4-decylphenyl



compound 264 R_1 = 2-ethylhexyl, R_2 = n-hexyl, R_7 = t-butyl, R_8 = n-butyloxy

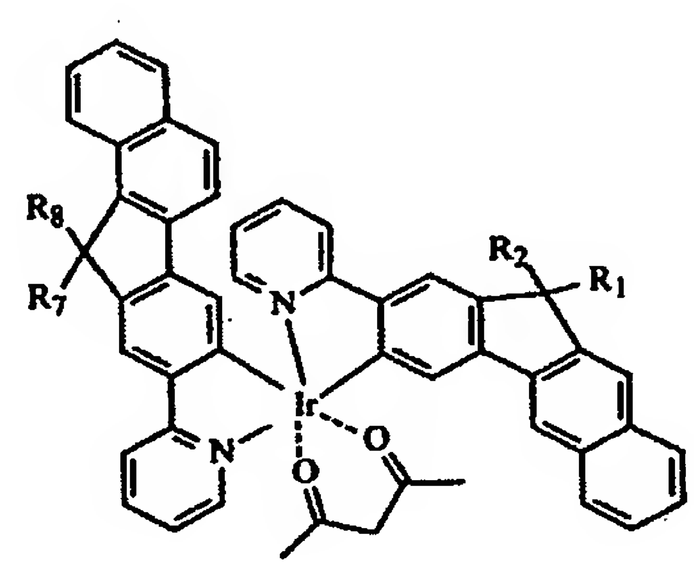
compound 265 $R_1 = R_2$ = n-hexyl, R_7 = phenyl, R_8 = H

compound 266 R_1 = 4-decylphenyl, $R_2 = R_7$ = 3,7-dimethyloctyl, R_8 = methoxy



compound 267 $R_1 = R_2 = R_7 = R_8 = R_9 = R_{10}$ = 2-ethylhexyl

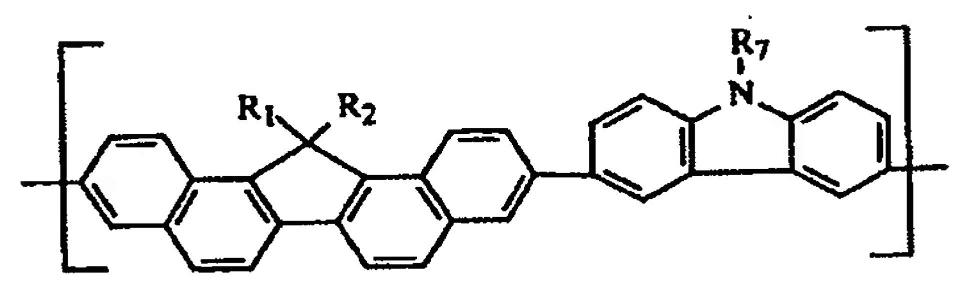
compound 268 $R_1 = R_7 = R_9$ = n-hexyl, $R_2 = R_8 = R_{10}$ = 4-t-butylphenyl



compound 269 $R_1 = R_2$ = n-hexyl, $R_7 = R_8$ = 2-ethylhexyl

compound 270 $R_1 = R_7 = H$, $R_2 = R_8 =$ 4-t-butylphenyl

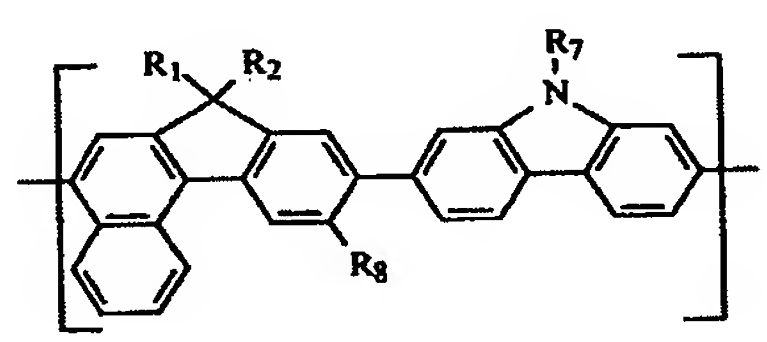
compound 271 $R_1 =$ 4-(diphenylamino)phenyl, $R_2 = R_7 =$ n-hexyl, $R_8 =$ 4-t-butylphenyl



compound 272 $R_1 = R_2 =$ n-hexyl, $R_7 =$ 2-ethylhexyl

compound 273 $R_1 =$ n-hexyl, $R_2 = R_7 =$ 2-ethylhexyl

compound 274 $R_1 = R_2 =$ 2-ethylhexyl, $R_7 =$ 4-t-butylphenyl

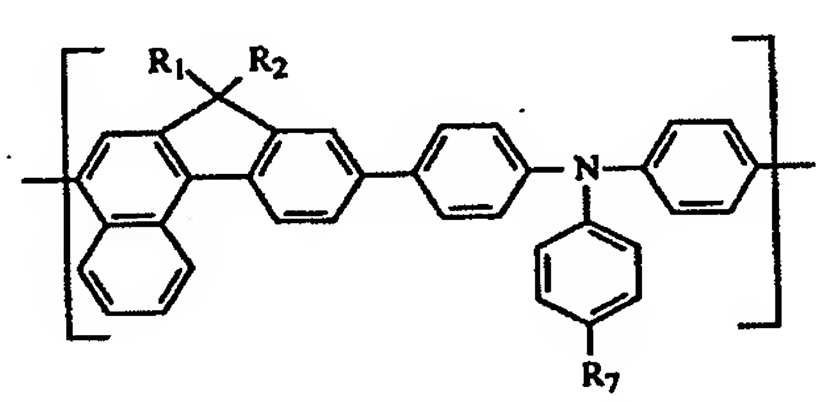


compound 275 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ 2-ethylhexyl

compound 276 $R_1 =$ 2-ethylhexyl, $R_2 =$ n-hexyl, $R_7 =$ 4-t-butylphenyl, $R_8 = H$

compound 277 $R_1 =$ n-hexyl, $R_2 = R_8 =$ 3,7-dimethyloctyl, $R_7 =$ (4-diphenylamino)phenyl

compound 278 $R_1 =$ phenyl, $R_2 =$ 4-decylphenyl, $R_7 =$ 2-ethylhexyl, $R_8 = H$

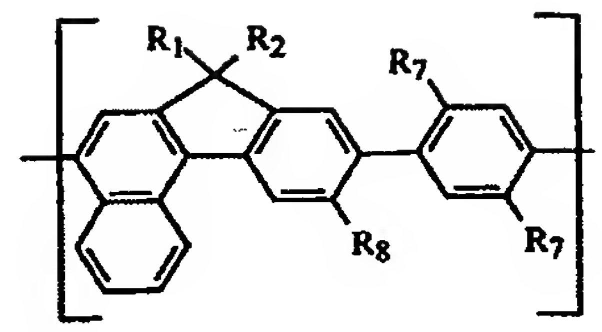


compound 279 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ n-butyl

compound 280 $R_1 = R_2 =$ n-hexyl, $R_7 =$ t-butyl, $R_8 = H$

compound 281 $R_1 = R_2 = R_7 = R_8 =$ n-hexyl

compound 282 $R_1 =$ 4-decylphenyl, $R_2 =$ phenyl, $R_7 =$ t-butyl, $R_8 = H$



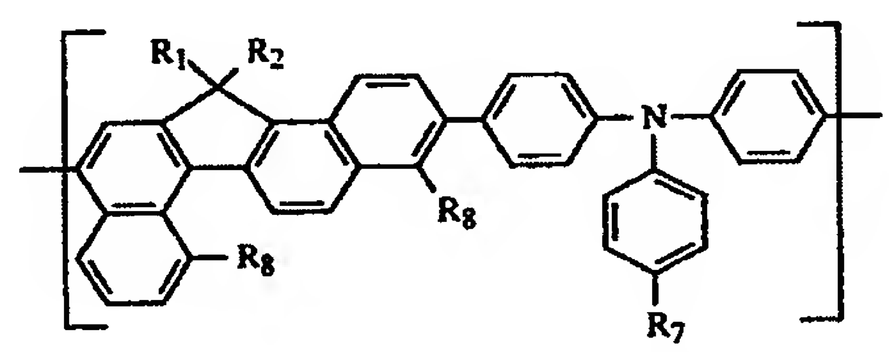
compound 283 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ n-butyl

compound 284 $R_1 = R_2 =$ n-hexyl, $R_7 =$ n-hexyloxy, $R_8 = H$

compound 285 $R_1 = R_2 = R_7 = R_8 =$ n-hexyl

compound 286 $R_1 = R_2 =$ n-hexyl, $R_7 =$ n-octyl, $R_8 = H$

compound 287 $R_1 =$ 4-decylphenyl, $R_2 =$ phenyl, $R_7 =$ t-butyl, $R_8 = H$

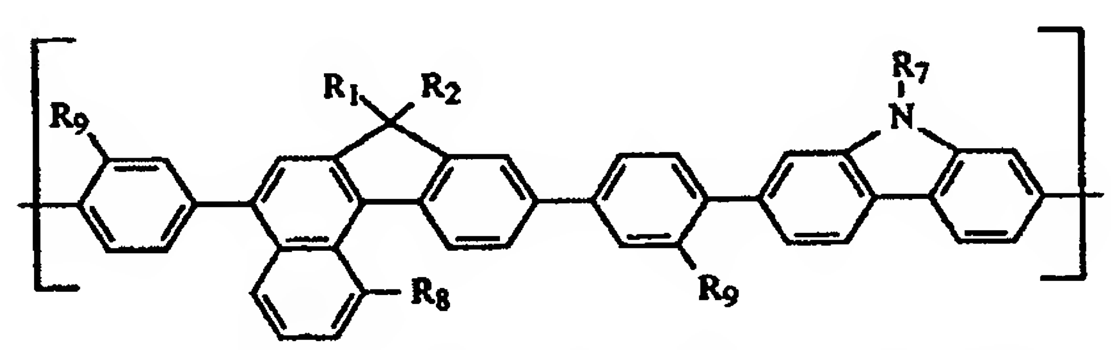


compound 288 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 =$ n-butyl

compound 289 $R_1 = R_2 =$ n-hexyl, $R_7 =$ t-butyl, $R_8 = H$

compound 290 $R_1 = R_2 = R_7 = R_8 =$ n-hexyl

compound 291 $R_1 =$ 4-decylphenyl, $R_2 =$ phenyl, $R_7 =$ t-butyl, $R_8 = H$



compound 292 $R_1 = R_2 =$ n-hexyl, $R_7 = R_8 = R_9 =$ 2-ethylhexyl

compound 293 $R_1 =$ 2-ethylhexyl, $R_2 =$ n-hexyl, $R_7 =$ 4-t-butylphenyl, $R_8 = R_9 =$ H

compound 294 $R_1 = R_2 = R_9 =$ 3,7-dimethyloctyl, $R_7 = R_8 =$ (4-diphenylamino)phenyl

compound 295 $R_1 =$ phenyl, $R_2 =$ 4-decylphenyl, $R_7 =$ 2-ethylhexyl, $R_8 = H$, $R_9 =$ di(4-methylphenyl)amino

The specific molecular structures can be the combination of any of the above drawn structures.

Organic compounds comprising complex fluorene structures (I), (II) or (III) can be synthesized using known methods. For polymers, the polymerization method and the molecular weights of the resulting polymers used in the present invention are not necessary to be particularly restricted. The molecular weights of the polymers are at least 1000, and preferably at least 2000. The polymers may be prepared by condensation polymerizations, such as coupling reactions including Pd-catalyzed Suzuki coupling, Stille coupling or Heck coupling, or Ni-mediated Yamamoto coupling, or by condensation reaction between di-(acid chlorides) with di-amines, di-alcohols or di-phenols in the presence of bases, or by other condensation methods such as Wittig reaction, or Horner-Emmons reaction, or Knoevenagel reaction, or dehalogenation of dibenzyl halides, or by free radical polymerization of vinyl compounds, or ring-opening polymerization cyclic compounds, or ring-opening metathesis polymerization. Preferably polymers are prepared by Suzuki coupling reaction.

Suzuki coupling reaction was first reported by Suzuki and others on the coupling of aromatic boronic acid derivatives with aromatic halides (Suzuki, A. and others *Synthetic Comm.* 1981, *11(7)*, 513). Since then, this reaction has been widely used to prepared polymers for various applications (Ranger, M. and others *Macromolecules* 1997, *30*, 7686). The reaction involves the use of a palladium-based catalyst such as a soluble Pd compound either in the state of Pd (II) or Pd (0), a base such as an aqueous inorganic alkaline carbonate or bicarbonate, and a solvent for the reactants and/or product. The preferred Pd catalyst is a Pd (0) complex such as $Pd(PPh_3)_4$ or a Pd (II) salt such as $Pd(PPh_3)_2Cl_2$ or $Pd(OAc)_2$ with a tertiary phosphine ligand, and used in the range of 0.01-10 mol% based on the functional groups of the reactants. Polar solvents such as THF and non-polar solvents toluene can be used however, the non-polar solvent is believed to slow down the reaction. Modified processes were reported to prepare conjugated polymers for EL devices from the Suzuki coupling of aromatic halides and aromatic boron derivatives (Inbasekaran, M. and others

US-A-5,777,070 (1998); Towns, C. R. and others PCT WO00/53656, 2000). A variation of the Suzuki coupling reaction replaces the aromatic halide with an aromatic trifluoromethanesulfonate (triflate) (Ritter, K. Synthesis, 1993, 735). Aromatic triflates are readily prepared from the corresponding phenol derivatives. The advantages of using aromatic triflates are that the phenol derivatives are easily accessible and can be protected/deprotected during complex synthesis. For example, aromatic halides normally would react under various coupling conditions to generate unwanted by-product and lead to much more complicated synthetic schemes. However, phenol derivatives can be easily protected by various protecting groups which would not interfere with functional group transformation and be deprotected to generate back the phenol group which then can be converted to triflates. The diboron derivatives can be prepared from the corresponding dihalide or ditriflate.

The present invention also provides a process for preparing a conjugated polymer which comprises in the polymerization reaction mixture (a) an aromatic monomer having at least two reactive triflate groups and an aromatic monomer having at least two reactive boron derivative groups selected from boronic acid, boronic ester, or borane groups or an aromatic monomer having one reactive triflate group and one boron derivative group selected from boronic acid, boronic ester, or borane groups, (b) a catalytic amount of a palladium catalyst, (c) an organic or inorganic base, and (d) an organic solvent. The process of the invention produces conjugated polymers with relatively low polydispersity, high molecular weight in a relatively short reaction time. The term "conjugated polymer" refers to either a fully conjugated polymer which is conjugated along the full length of its chain and processes a delocalized pi-electron system along the chain, or a partially conjugated polymer which contains both conjugated and non-conjugated segments.

The aromatic monomers used to form conjugated polymers of the present invention must have the appropriate functional groups: the triflate and boron derivative groups. The term aromatic or aryl refers to any monomer which has triflate or boron derivative groups attached directly to the aromatic or

heteroaromatic rings. The present process can be used to polymerize two systems to form a linear polymer: 1) an aryl di-triflate monomer containing two reactive triflate groups and an aryl di-boron monomer containing two reactive boron derivative functional groups; and 2) an aryl monomer containing both reactive triflate and boron derivative functional groups. To prepare branched or hyperbranched polymers using the process of the invention, in a two monomers system, both aryl monomers must contain at least two reactive triflate or boron derivative groups; in a one monomer system, the monomer must contain at least one of the triflate or boron derivative groups and more than one the other group. The boron derivative functional groups are selected from a boronic acid group represented by $B(OH)_2$, a boronic ester group represented by $B(OR_{12})(OR_{13})$ wherein R_{12} is substituted or unsubstituted alkyl group of 1 to 6 carbons, and R_{13} is hydrogen, or substituted and unsubstituted alkyl group of 1 to 6 carbons, R_{12} and R_{13} can be the same or different, and R_{12} and R_{13} can be connected to form a cyclic boronic ester, preferably a 5- or 6-membered ring; and a borane group represented by $BR_{14}R_{15}$, wherein R_{14} and R_{15} are each substituted and unsubstituted alkyl group of 1 to 20 carbons. The boron derivative groups are preferably boronic acid or cyclic boronic ester groups. Polymers can be prepared by using a mixture of monomers to form copolymers with desired properties and architecture. To prepare linear polymers, the polymerization system preferably comprises about equal mole percent of the reactive triflate and boron derivative groups. The mole ratio of these two classes of reactive groups is preferably 0.98 to 1.10, more preferably less than 1.05, most preferably 1.00. If desired, a mono-functional triflate or boron derivative can be used to end-cap the chain ends.

Examples of the aryl groups for the monomers include but are not limited to aromatic hydrocarbons such as phenyl, naphthyl, anthracene, fluorene, benzofluorene, dibenzofluorene, phenanthrene, perylene, pyrene, rubrene, chrysene, tetracene, pentacene, triphenylene, diphenylanthracene, dinapthylanthracene, and benzo[a]pyrene; and heteroaromatic groups such as thiophene, pyrrole, furan, pyridine, triazines, tetrazenes, oxazoles, imidazoles, oxadiazole, thiadiazole, benzoxazole, quinoline, benzimidazole, carbazole,

benzothiazole, and acridine; and triarylamines such as triphenylamine, dinaphthylphenylamine, and N,N'-diphenylbenzidine. Preferably, the aryl groups are selected from fluorene, benzofluorene, diphenylanthracene, dinaphthylanthracene, thiophene, oxadiazole, benzothiazole, benzimidazole and carbazole.

The bases suitable for use in the process of the invention include inorganic aqueous bases such as alkali metal hydroxides, carbonates acetates, and bicarbonates, alkaline earth metal hydroxides, carbonates acetates, and bicarbonates, alkaline earth metal alkoxides, and alkali metal alkoxides, and organic bases such as sources of hydroxyl ions and Lewis bases such as those which create a source of hydroxyl ions in the presence of water. The organic base should be soluble in an organic solvent and/or water. Examples of aqueous inorganic bases include the hydroxide, carbonates and bicarbonates of lithium, sodium, potassium, cesium, and barium. Preferably, the aqueous base is a solution of sodium, potassium, or cesium carbonate in a concentration of 1 to 2 M. Examples of organic bases include alkyl ammonium hydroxides, carbonates, bicarbonates, fluorides, and borates, pyridines, organic amines. Preferably, the organic base used in the process of the invention is a tetraalkylammonium hydroxide, carbonate, or bicarbonate such as tetramethyl-, tetraethyl-, or tetrapropyl-ammonium hydroxide, carbonate, or bicarbonate. The amount of base used in the process is not particularly important as long as the number of moles of the base is equal or higher than that of the monomer. Preferably, 1 to 10 molar equivalents of the base per boron-derivative functional group are employed. More preferably, 1 to 5 molar equivalents of base are used. Most preferably, 1.5 to 4 molar equivalents, and in particular 1.8 to 2.5 molar equivalents of base are used. A single base or a mixture of different bases can be used in the process of the invention.

The catalyst used in the process of the invention is preferably a palladium catalyst in a form of Pd(0) or Pd(II) complexes with ligands or Pd(II) salts. Examples of the suitable ligands for the palladium complexes are phosphines such as trialkylphophines, tricycloalkylphosphines and triarylphosphines, where the

three substituents on the phosphorus can be identical or different and one or more of the ligands can link phophorus groups of a plurality of phosphines, where part of this linkage can also be one or me metal atoms, diketones such asdibenzylideneacetone (dba), acetylacetone and octafluoroacetylacetone, and tertiary amines such as triethylamine, trimethylamine, tripropylamines. These ligands can also be derivatized by attachment of cationic or anionic groups to render water solubility. It is also possible to use a mixture of more than one ligand. Particular examples of the phosphine ligands used in the process of the invention are trimethylphosphine, tributylphophine, tricyclohexylphosphine, tritolylphosphine, 1,2-bis(diphenylphosphino)ethane, triphenylphosphine, 1,3-bis(diphenylphosphino)propane, and 1,1'-(diphenylphosphineo)ferrocene (dppf). Preferably, the ligands are triphenylphosphine (Ph_3P), 1,1'-(diphenlphosphineo)ferrocene (dppf), 1,2-bis(diphenylphosphino)ethane, and 1,3-(bisdiphenylphosphino)propane, and more preferably, triphenylphosphine (Ph_3P), and 1,1'-(diphenlphosphineo)ferrocene (dppf). The most preferred Pd(0) complex is $Ph(Ph_3P)_4$. The preferred Pd(II) salts are palladium acetate, palladium (II) propionate, palladium (II) butanoate, and palladium (II) chloride, and more preferred Pd (II) salt is palladium (II) acetate. When a palladium (II) salt is used, it is advantageous to add to the reaction mixture 2 to 4 molar equivalents of other ligands such as Ph_3P or dppf per mole of Pd salt. A Pd(II) complex such as $PdCl_2(PPh_3)_2$, bis(acetonitrile)palladium dichloride, dichlorobis(dimethylsulfoxide) palladium (II), bis(benzonitrile)palladium dichloride, or $PdCl_2$(dppf) can be used as an alternative. The palladium catalyst can also be on a support material such as an inert organic resin. Typically, the amount of the palladium catalyst used in the reaction mixture is 0.001 to 1 mol% for each mole of monomer, preferably, 0.01 to 1 mol% for each mole of monomer.

The organic solvents suitable for use in the process include those capable of dissolving the monomer to a solution concentration of at least 1 percent, preferably at least 2 percent. Examples of suitable solvents for the process described are hydrocarbons such as hexane, heptane, petroleum ether, cyclohexane, benzene, chlorobenzenes, ethylbenzen,mesitylene, toluene, and

xylenes, ethers such as anisole, diethyl ether, tetrahydrofuran, dioxane, dioxolane, diisopropyl ether, dimethoxyethane, t-butyl methyl ether, and diethylene glycol dimethyl ether, ketones such as acetone, methyl ethyl ketone, and isobutyl methyl ketone, alcohols such as methanol, ethanol, propanols, ethylene glycol, and butanols, and amides such as dimethylformamide, dimethylactamide and N-methylpyrrolidone, and the florinated analog thereof, and the mixtures thereof.

The preferred organic solvents include one solvent in which the polymer is soluble. Examples of the preferred solvents are ethers such as tetrahydrofuran, dioxane, dimethyoxyethane, diethylene glycol dimethyl ether, diisopropyl ether, hydrocarbons such as benzene, chlorobenzenes, toluene, xylenes, heptane, and cyclohexane, ketones such as methyl ethyl ketone and isobutyl methyl ketone, amides such as dimethylformamide, dimethylacetamide and N-methylpyrrolidone, and mixtures thereof.

More preferred organic solvents are ethers for example tetrahydrofuran, dimethyoxyethane and dioxane, hydrocarbons for example toluene, chlorobenzenes, and xylenes, and amides for example, dimethylformamide, and dimethylacetamide.

Most preferred organic solvents of the process of the invention are one or more water-insoluble solvents such as toluene or xylenes or tetrahydrofuran, or mixtures thereof. The volume of the solvent of the process of the invention should be maintained at the level for efficient mixing and stirring at reflux as the reaction mixture becomes more viscous with the build-up of polymer molecular weight.

The polymerization reaction mixture may also contain a phase transfer catalyst as disclosed in US-A-5,777,070. Suitable phase transfer catalysts used in the process of the invention include quaternary ammonium and phosphonium salts, crown ethers and cryptands. Preferably, the phase transfer catalyst is a tetralkylammonium halide, or bisulfate. Examples of the most preferred phase transfer catalyst are tetrabutylammonium chloride and tricaprylylmethylammonium chloride (known as Aliquat® from Aldrich Chemical). The preferred range of the amount of phase transfer catalyst is

between 0.01 to 0.5 mole per mole of monomer, more preferably 0.05 to 0.1 mole per mole of monomer.

The polymerization reaction is carried at a temperature of from 0 to 200 °C, preferably from 30 to 170 °C, and more preferably 50 to 150 °C, and most preferably 60 to 120 °C. The reaction time is from 1 to 100 hours, preferably 5 to 70 hours, more preferably 5 to 50 hours, and most preferably, 5 to 48 hours.

The process of the present invention can also be extended to the use of monomers in which some or all of the reactive functional groups are not directly attached to the aromatic rings, especially to other kinds of unsaturated monomers.

The synthetic schemes of the compounds according to the present invention are illustrated in Schemes 1-11.

The process of the invention provides conjugated polymers particularly useful for an optical device. The optical device may comprise a luminescent device such as an EL device in which the polymer or small molecules of the present invention is deposited between a cathode and an anode. The polymers or small molecules or the combination thereof can be deposited as thin film by vapor deposition method or from a solution by spin-coating, spray-coating, dip-coating, roller-coating, or ink jet delivery. The thin film may be supported by substrate directly, preferably a transparent substrate, or supported by the substrate indirectly where there is one or more inter layers between the substrate and thin film. The thin film can be used as emitting layer or charge carrier transporting layer.

General EL device architecture:

The present invention can be employed in most organic EL device configurations. These include very simple structures comprising a single anode and cathode to more complex devices, such as passive matrix displays comprised of orthogonal arrays of anodes and cathodes to form pixels, and active-matrix displays where each pixel is controlled independently, for example, with thin film transistors (TFTs).

There are numerous configurations of the organic layers wherein the present invention can be successfully practiced. A typical structure is shown in FIG. 1 and includes a substrate 101, an anode 103, a hole-injecting layer 105, a hole-transporting layer 107, a light-emitting layer 109, an electron-transporting layer 111, and a cathode 113. These layers are described in detail below. This figure is for illustration only and the individual layer thickness is not scaled according to the actual thickness. Note that the substrate may alternatively be located adjacent to the cathode, or the substrate may actually constitute the anode or cathode. The organic layers between the anode and cathode are conveniently referred to as the organic EL element. Also, the total combined thickness of the organic layers is preferably less than 500 nm.

The anode and cathode of the OLED are connected to a voltage/current source 250 through electrical conductors 260. The OLED is operated by applying a potential between the anode and cathode such that the anode is at a more positive potential than the cathode. Holes are injected into the organic EL element from the anode and electrons are injected into the organic EL element at the anode. Enhanced device stability can sometimes be achieved when the OLED is operated in an AC mode where, for some time period in the cycle, the potential bias is reversed and no current flows. An example of an AC driven OLED is described in US-A-5,552,678.

Substrate:

The OLED device of this invention is typically provided over a supporting substrate 101 where either the cathode or anode can be in contact with the substrate. The electrode in contact with the substrate is conveniently referred

to as the bottom electrode. Conventionally, the bottom electrode is the anode, but this invention is not limited to that configuration. The substrate can either be light transmissive or opaque, depending on the intended direction of light emission. The light transmissive property is desirable for viewing the EL emission through the substrate. Transparent glass or plastic is commonly employed in such cases. The substrate may be a complex structure comprising multiple layers of materials. This is typically the case for active matrix substrates wherein TFTs are provided below the EL layers. It is still necessary that the substrate, at least in the emissive pixilated areas, be comprised of largely transparent materials such as glass or polymers. For applications where the EL emission is viewed through the top electrode, the transmissive characteristic of the bottom support is immaterial, and therefore can be light transmissive, light absorbing or light reflective. Substrates for use in this case include, but are not limited to, glass, plastic, semiconductor materials, silicon, ceramics, and circuit board materials. Again, the substrate may be a complex structure comprising multiple layers of materials such as found in active matrix TFT designs. Of course it is necessary to provide in these device configurations a light-transparent top electrode.

Anode:

When EL emission is viewed through anode 103, the anode should be transparent or substantially transparent to the emission of interest. Common transparent anode materials used in this invention are indium-tin oxide (ITO), indium-zinc oxide (IZO) and tin oxide, but other metal oxides can work including, but not limited to, aluminum- or indium-doped zinc oxide, magnesium-indium oxide, and nickel-tungsten oxide. In addition to these oxides, metal nitrides, such as gallium nitride, and metal selenides, such as zinc selenide, and metal sulfides, such as zinc sulfide, can be used as the anode 103. The anode can be modified with plasma-deposited fluorocarbons. For applications where EL emission is viewed only through the cathode electrode, the transmissive characteristics of anode are immaterial and any conductive material can be used, transparent, opaque or reflective. Example conductors for this application include, but are not limited to, gold, iridium, molybdenum, palladium, and platinum. Typical anode

materials, transmissive or otherwise, have a work function of 4.1 eV or greater. Desired anode materials are commonly deposited by any suitable means such as evaporation, sputtering, chemical vapor deposition, or electrochemical means. Anodes can be patterned using well-known photolithographic processes. Optionally, anodes may be polished prior to application of other layers to reduce surface roughness so as to minimize shorts or enhance reflectivity.

Hole-Injection Layer (HIL):

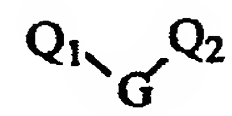
While not always necessary, it is often useful that a hole-injecting layer 105 be provided between anode 103 and hole-transporting layer 107. The hole-injecting material can serve to improve the film formation property of subsequent organic layers and to facilitate injection of holes into the hole-transporting layer. Suitable materials for use in the hole-injecting layer include, but are not limited to, porphyrinic compounds as described in US-A-4,720,432, plasma-deposited fluorocarbon polymers as described in US-A-6,208,075, and some aromatic amines, for example, m-MTDATA (4,4',4"-tris[(3-methylphenyl)phenylamino]triphenylamine). Alternative hole-injecting materials reportedly useful in organic EL devices are described in EP 0 891 121 A1 and EP 1 029 909 A1.

Hole-Transporting Layer (HTL)

The hole-transporting layer 107 of the organic EL device in general contains at least one hole-transporting compound such as an aromatic tertiary amine, where the latter is understood to be a compound containing at least one trivalent nitrogen atom that is bonded only to carbon atoms, at least one of which is a member of an aromatic ring. In one form the aromatic tertiary amine can be an arylamine, such as a monoarylamine, diarylamine, triarylamine, or a polymeric arylamine. Exemplary monomeric triarylamines are illustrated by Klupfel and others US-A-3,180,730. Other suitable triarylamines substituted with one or more vinyl radicals and/or comprising at least one active hydrogen containing group are disclosed by Brantley and others US-A-3,567,450 and US-A-3,658,520.

A more preferred class of aromatic tertiary amines are those which include at least two aromatic tertiary amine moieties as described in US-A-4,720,432 and

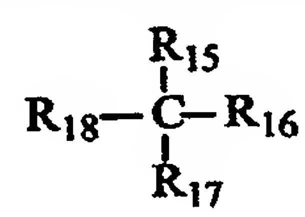
US-A-5,061,569. Such compounds include those represented by structural formula (A).



(A)

wherein Q_1 and Q_2 are independently selected aromatic tertiary amine moieties and G is a linking group such as an arylene, cycloalkylene, or alkylene group of a carbon to carbon bond. In one embodiment, at least one of Q_1 or Q_2 contains a polycyclic fused ring structure, for example, a naphthalene. When G is an aryl group, it is conveniently a phenylene, biphenylene, or naphthalene moiety.

A useful class of triarylamines satisfying structural formula (A) and containing two triarylamine moieties is represented by structural formula (B):

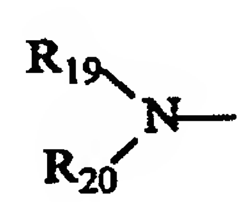


(B)

wherein:

R_{15} and R_{16} each independently represents a hydrogen atom, an aryl group, or an alkyl group or R_1 and R_2 together represent the atoms completing a cycloalkyl group; and

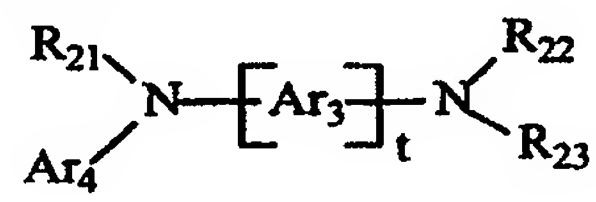
R_{17} and R_{18} each independently represents an aryl group, which is in turn substituted with a diaryl substituted amino group, as indicated by structural formula (C):



(C)

wherein R_{19} and R_{20} are independently selected aryl groups. In one embodiment, at least one of R_{19} or R_{20} contains a polycyclic fused ring structure, for example, a naphthalene.

Another class of aromatic tertiary amines are the tetraaryldiamines. Desirable tetraaryldiamines include two diarylamino groups, such as indicated by formula (C), linked through an arylene group. Useful tetraaryldiamines include those represented by formula (D):



(D)

wherein

each Ar_3 is an independently selected arylene group, such as a phenylene or anthracene moiety,

t is an integer of from 1 to 4, and

Ar_4, R_{21}, R_{22}, and R_{23} are independently selected aryl groups.

In a typical embodiment, at least one of Ar_4, R_{21}, R_{22}, and R_{23} is a polycyclic fused ring structure, for example, a naphthalene.

The various alkyl, alkylene, aryl, and arylene moieties of the foregoing structural formulae (A), (B), (C), (D), can each in turn be substituted. Typical substituents include alkyl groups, alkoxy groups, aryl groups, aryloxy groups, and halogen such as fluoride, chloride, and bromide. The various alkyl and alkylene moieties typically contain from about 1 to 6 carbon atoms. The cycloalkyl moieties can contain from 3 to about 10 carbon atoms, but typically contain five, six, or seven ring carbon atoms -- for example, cyclopentyl, cyclohexyl, and cycloheptyl ring structures. The aryl and arylene moieties are usually phenyl and phenylene moieties.

The hole-transporting layer can be formed of a single or a mixture of aromatic tertiary amine compounds. Specifically, one may employ a triarylamine, such as a triarylamine satisfying the formula (B), in combination with a tetraaryldiamine, such as indicated by formula (D). When a triarylamine is employed in combination with a tetraaryldiamine, the latter is positioned as a layer interposed between the triarylamine and the electron injecting and transporting layer. Illustrative of useful aromatic tertiary amines are the following:

1,1-Bis(4-di-*p*-tolylaminophenyl)cyclohexane
1,1-Bis(4-di-*p*-tolylaminophenyl)-4-phenylcyclohexane
4,4'-Bis(diphenylamino)quadriphenyl
Bis(4-dimethylamino-2-methylphenyl)-phenylmethane
N,N,N-Tri(*p*-tolyl)amine
4-(di-p-tolylamino)-4'-[4(di-*p*-tolylamino)-styryl]stilbene
N,N,N',N'-Tetra-*p*-tolyl-4-4'-diaminobiphenyl
N,N,N',N'-Tetraphenyl-4,4'-diaminobiphenyl
N,N,N',N'-tetra-1-naphthyl-4,4'-diaminobiphenyl
N,N,N',N'-tetra-2-naphthyl-4,4'-diaminobiphenyl
N-Phenylcarbazole
4,4'-Bis[N-(1-naphthyl)-N-phenylamino]biphenyl
4,4'-Bis[N-(1-naphthyl)-N-(2-naphthyl)amino]biphenyl
4,4"-Bis[N-(1-naphthyl)-N-phenylamino]p-terphenyl
4,4'-Bis[N-(2-naphthyl)-N-phenylamino]biphenyl
4,4'-Bis[N-(3-acenaphthenyl)-N-phenylamino]biphenyl
1,5-Bis[N-(1-naphthyl)-N-phenylamino]naphthalene
4,4'-Bis[N-(9-anthryl)-N-phenylamino]biphenyl
4,4"-Bis[N-(1-anthryl)-N-phenylamino]-*p*-terphenyl
4,4'-Bis[N-(2-phenanthryl)-N-phenylamino]biphenyl
4,4'-Bis[N-(8-fluoranthenyl)-N-phenylamino]biphenyl
4,4'-Bis[N-(2-pyrenyl)-N-phenylamino]biphenyl
4,4'-Bis[N-(2-naphthacenyl)-N-phenylamino]biphenyl
4,4'-Bis[N-(2-perylenyl)-N-phenylamino]biphenyl
4,4'-Bis[N-(1-coronenyl)-N-phenylamino]biphenyl
2,6-Bis(di-*p*-tolylamino)naphthalene
2,6-Bis[di-(1-naphthyl)amino]naphthalene
2,6-Bis[N-(1-naphthyl)-N-(2-naphthyl)amino]naphthalene
N,N,N',N'-Tetra(2-naphthyl)-4,4"-diamino-*p*-terphenyl
4,4'-Bis{N-phenyl-N-[4-(1-naphthyl)-phenyl]amino}biphenyl
4,4'-Bis[N-phenyl-N-(2-pyrenyl)amino]biphenyl

2,6-Bis[N,N-di(2-naphthyl)amine]fluorene

1,5-Bis[N-(1-naphthyl)-N-phenylamino]naphthalene

4,4',4"-tris[(3-methylphenyl)phenylamino]triphenylamine

Another class of useful hole-transporting materials includes polycyclic aromatic compounds as described in EP 1 009 041. Tertiary aromatic amines with more than two amine groups may be used including oligomeric materials. In addition, polymeric hole-transporting materials can be used such as poly(N-vinylcarbazole) (PVK), polythiophenes, polypyrrole, polyaniline (Yang, Y. and others *Appl. Phys. Lett.* 1994, 64, 1245) and copolymers such as poly(3,4-ethylenedioxythiophene) / poly(4-styrenesulfonate) also called PEDOT/PSS(Groenendaal, L. B. and others *Adv. Mater.* 2000, 12, 481).

Light-Emitting Layer (LEL)

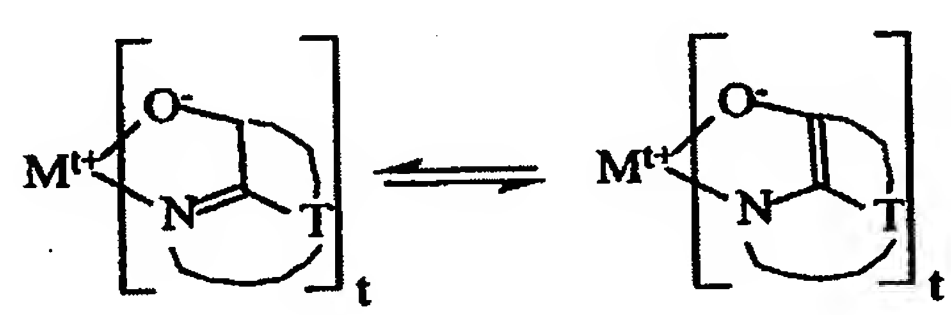
As more fully described in commonly-assigned US-A-4,769,292 and US-A-5,935,721, the light-emitting layer (LEL) 109 of the organic EL element includes a luminescent or fluorescent material where electroluminescence is produced as a result of electron-hole pair recombination in this region. The light-emitting layer can be comprised of a single material including both small molecules and polymers, but more commonly consists of a host material doped with a guest compound or compounds where light emission comes primarily from the dopant and can be of any color. The host materials in the light-emitting layer can be an electron-transporting material, as defined below, a hole-transporting material, as defined above, or another material or combination of materials that support hole-electron recombination. The dopant is usually chosen from highly fluorescent dyes, but phosphorescent compounds, for example, transition metal complexes as described in WO 98/55561, WO 00/18851, WO 00/57676, and WO 00/70655 are also useful. Simultaneously, the color of the EL devices can be tuned using dopants of different emission wavelengths. By using a mixture of dopants, EL color characteristics of the combined spectra of the individual dopant are produced. This dopant scheme has been described in considerable detail for EL devices in commonly-assigned US-A-4,769,292 for fluorescent dyes. Dopants are typically coated as 0.01 to 10 % by weight into the host material. Polymeric

materials such as polyfluorenes and poly(arylene vinylenes) (for example, poly(p-phenylenevinylene), PPV) can also be used as the host material. In this case, small molecule dopants can be molecularly dispersed into the polymeric host, or the dopant could be added by copolymerizing a minor constituent into the host polymer.

An important relationship for choosing a dye as a dopant is a comparison of the bandgap potential which is defined as the energy difference between the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) of the molecule. For efficient energy transfer from the host to the dopant molecule, a necessary condition is that the band gap of the dopant is smaller than that of the host material. For phosphorescent emitters it is also important that the host triplet energy level of the host be high enough to enable energy transfer from host to dopant.

For small molecules, host and emitting molecules known to be of use include, but are not limited to, those disclosed in US-A-4,768,292; US-A-5,141,671; US-A-5,150,006; US-A-5,151,629; US-A-5,405,709; US-A-5,484,922; US-A-5,593,788; US-A-5,645,948; US-A-5,683,823; US-A-5,755,999; US-A-5,928,802; US-A-5,935,720; US-A-5,935,721, and US-A-6,020,078.

For example, small molecule metal complexes of 8-hydroxyquinoline and similar derivatives (Formula E) constitute one class of useful host compounds capable of supporting electroluminescence, and are particularly suitable for light emission of wavelengths longer than 500 nm, for example, green, yellow, orange, and red.



(E)

wherein:

M represents a metal;

t is an integer of from 1 to 4; and

T independently in each occurrence represents the atoms completing a nucleus having at least two fused aromatic rings.

From the foregoing it is apparent that the metal can be monovalent, divalent, trivalent, or tetravalent metal. The metal can, for example, be an alkali metal, such as lithium, sodium, or potassium; an alkaline earth metal, such as magnesium or calcium; an earth metal, such aluminum or gallium, or a transition metal such as zinc or zirconium. Generally any monovalent, divalent, trivalent, or tetravalent metal known to be a useful chelating metal can be employed.

T completes a heterocyclic nucleus containing at least two fused aromatic rings, at least one of which is an azole or azine ring. Additional rings, including both aliphatic and aromatic rings, can be fused with the two required rings, if required. To avoid adding molecular bulk without improving on function the number of ring atoms is usually maintained at 18 or less.

Illustrative of useful chelated oxinoid compounds are the following:

CO-1: Aluminum trisoxine [alias, tris(8-quinolinolato)aluminum(III)]

CO-2: Magnesium bisoxine [alias, bis(8-quinolinolato)magnesium(II)]

CO-3: Bis[benzo{f}-8-quinolinolato]zinc (II)

CO-4: Bis(2-methyl-8-quinolinolato)aluminum(III)-μ-oxo-bis(2-methyl-8-quinolinolato) aluminum(III)

CO-5: Indium trisoxine [alias, tris(8-quinolinolato)indium]

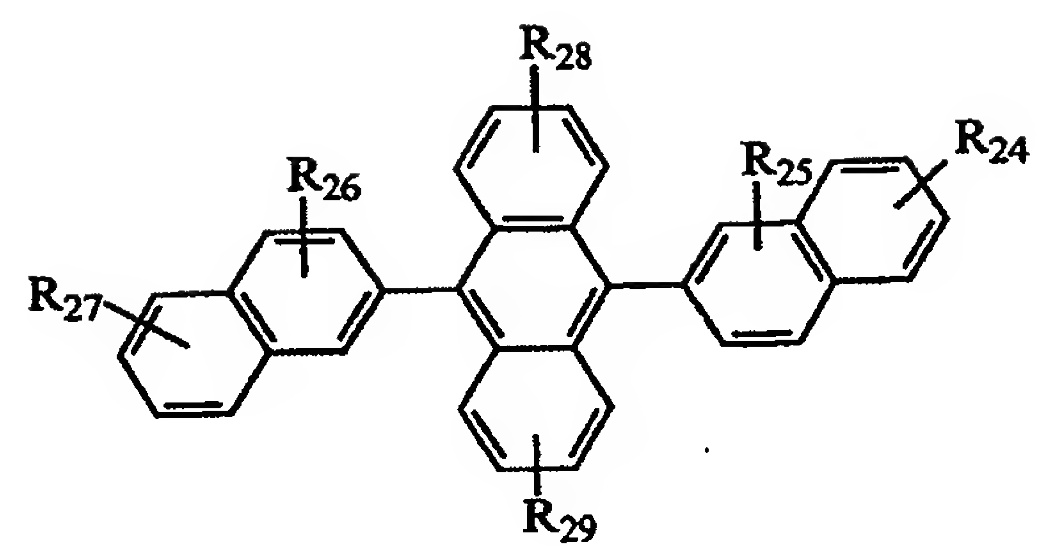
CO-6: Aluminum tris(5-methyloxine) [alias, tris(5-methyl-8-quinolinolato) aluminum(III)]

CO-7: Lithium oxine [alias, (8-quinolinolato)lithium(I)]

CO-8: Gallium oxine [alias, tris(8-quinolinolato)gallium(III)]

CO-9: Zirconium oxine [alias, tetra(8-quinolinolato)zirconium(IV)]

Derivatives of 9,10-di-(2-naphthyl)anthracene (Formula F) constitute one class of useful hosts capable of supporting electroluminescence, and are particularly suitable for light emission of wavelengths longer than 400 nm, for example., blue, green, yellow, orange or red.



(F)

wherein: R_{24}, R_{25}, R_{26}, R_{27}, R_{28}, and R_{29} represent one or more substituents on each ring where each substituent is individually selected from the following groups:

Group 1: hydrogen, or alkyl of from 1 to 24 carbon atoms;

Group 2: aryl or substituted aryl of from 5 to 20 carbon atoms;

Group 3: carbon atoms from 4 to 24 necessary to complete a fused aromatic ring of anthracenyl; pyrenyl, or perylenyl;

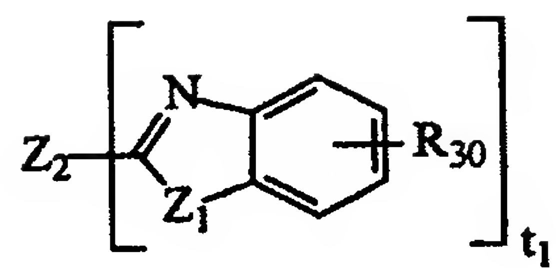
Group 4: heteroaryl or substituted heteroaryl of from 5 to 24 carbon atoms as necessary to complete a fused heteroaromatic ring of furyl, thienyl, pyridyl, quinolinyl or other heterocyclic systems;

Group 5: alkoxylamino, alkylamino, or arylamino of from 1 to 24 carbon atoms; and

Group 6: fluorine, chlorine, bromine or cyano.

Illustrative examples include 9,10-di-(2-naphthyl)anthracene and 2-*t*-butyl-9,10-di-(2-naphthyl)anthracene. Other anthracene derivatives can be useful as a host in the LEL, including derivatives of 9,10-bis[4-(2,2-diphenylethenyl)phenyl]anthracene.

Benzazole derivatives (Formula G) constitute another class of useful hosts capable of supporting electroluminescence, and are particularly suitable for light emission of wavelengths longer than 400 nm, for example, blue, green, yellow, orange or red.



(G)

wherein:

t_1 is an integer of 3 to 8;

Z_1 is O, NR_{31} or S; and

R_{30} and R_{31} are individually hydrogen; alkyl of from 1 to 24 carbon atoms, for example, propyl, t-butyl, heptyl, and the like; aryl or hetero-atom substituted aryl of from 5 to 20 carbon atoms for example phenyl and naphthyl, furyl, thienyl, pyridyl, quinolinyl and other heterocyclic systems; or halo such as chloro, fluoro; or atoms necessary to complete a fused aromatic ring;

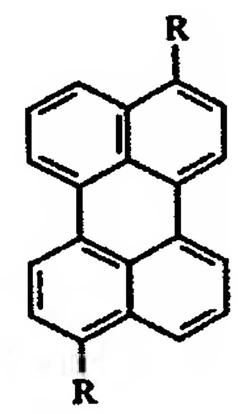
Z_2 is a linkage unit consisting of alkyl, aryl, substituted alkyl, or substituted aryl, which conjugately or unconjugately connects the multiple benzazoles together. An example of a useful benzazole is 2, 2', 2''-(1,3,5-phenylene)tris[1-phenyl-1H-benzimidazole].

Distyrylarylene derivatives are also useful hosts, as described in US-A-5,121,029. Carbazole derivatives are particularly useful hosts for phosphorescent emitters.

Polymers incorporating the above small molecule moieties as represented by formulas (E), (F), and (G) are useful host materials. Examples of 9,10-di-(2-naphthyl)anthracene-containing polymers are disclosed in US-A-6,361,887.

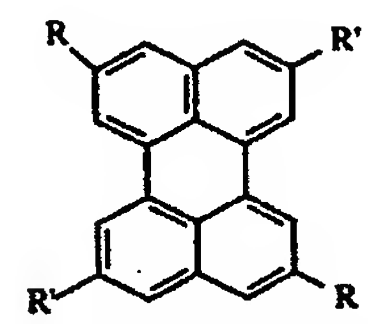
Useful fluorescent dopants (FD) include, but are not limited to, derivatives of anthracene, tetracene, xanthene, perylene, rubrene, coumarin, rhodamine, and quinacridone, dicyanomethylenepyran compounds, thiopyran compounds, polymethine compounds, pyrilium and thiapyrilium compounds, fluorene derivatives, periflanthene derivatives, indenoperylene derivatives, bis(azinyl)amine boron compounds, bis(azinyl)methane compounds, and carbostyryl compounds. Useful phosphorescent dopants (PD) include but are not

limited to organometallic complexes of transition metals of iridium, platinum, palladium, or osmium. Illustrative examples of useful dopants include, but are not limited to, the following:



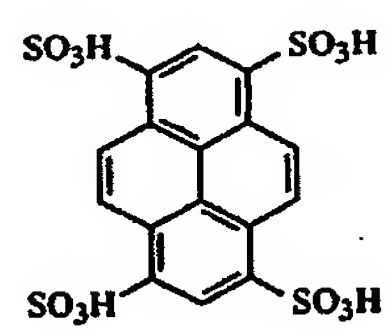
FD 1 R = H

FD 2 R = CO_2Pr-i

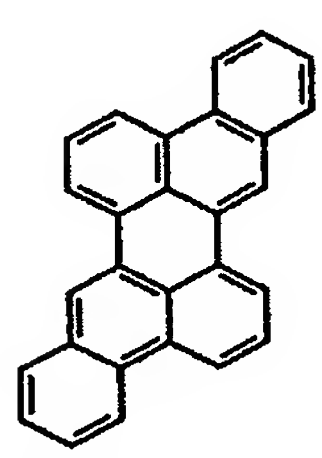


FD 3 R = H, R' = t-Bu

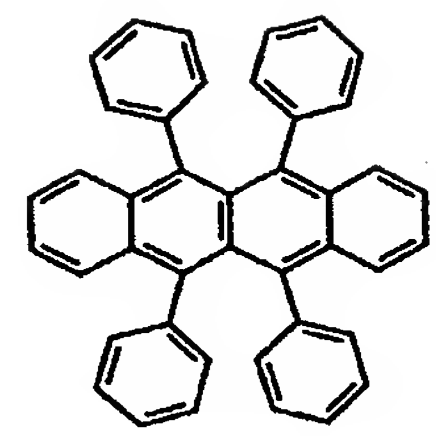
FD 4 R = R' = t-Bu



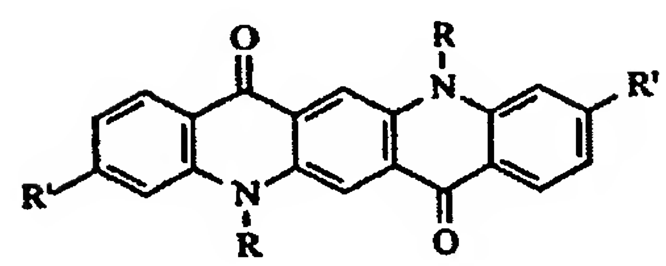
FD 5



FD 6



FD 7



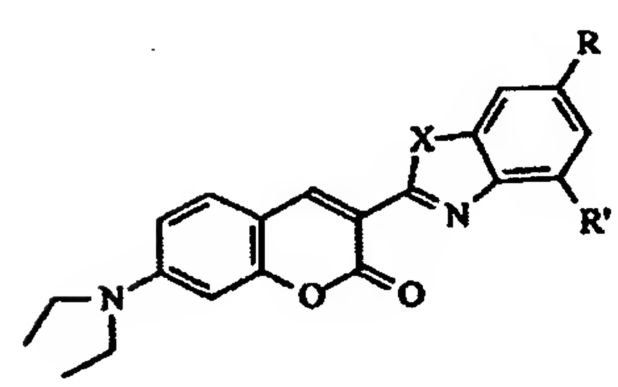
FD 8 R = R' = H

FD 9 R = Me, R' = H

FD 10 R = Pr-i, R' = H

FD 11 R = Me, R' = F

FD 12 R = phenyl, R' =H



FD 13 R = R' = H, X = O

FD 14 R = H, R' = Me, X = O

FD 15 R = Me, R' = H, X = O

FD 16 R = Me, R' = Me, X = O

FD 17 R = H, R' = t-Bu, X = O

FD 18 R = t-Bu, R' = H, X = O

FD 19 R = R' = t-Bu, X = O

FD 20 R = R' = H, X = S

FD 21 R = H, R' = Me, X = S

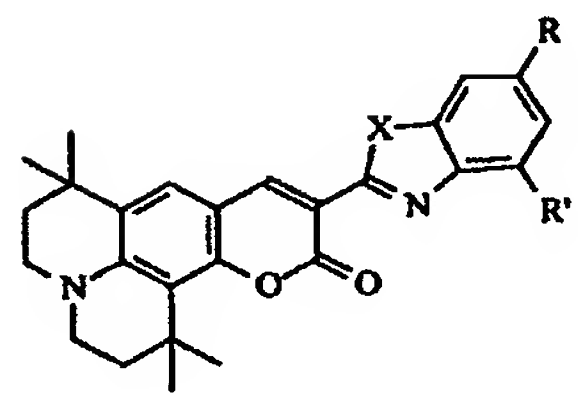
FD 22 R = Me, R' = H, X = S

FD 23 R = Me, R' = Me, X = S

FD 24 R = H, R' = t-Bu, X = S

FD 25 R = t-Bu, R' = H, X = S

FD 26 R = R' = t-Bu, X = S



FD 27 R = R' = H, X = O

FD 28 R = H, R' = Me, X = O

FD 29 R = Me, R' = H, X = O

FD 30 R = Me, R' = Me, X = O

FD 31 R = H, R' = t-Bu, X = O

FD 32 R = t-Bu, R' = H, X = O

FD 33 R = R' = t-Bu, X = O

FD 34 R = R' = H, X = S

FD 35 R = H, R' = Me, X = S

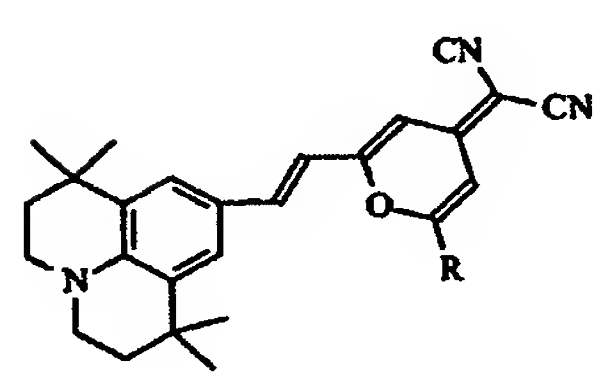
FD 36 R = Me, R' = H, X = S

FD 37 R = Me, R' = Me, X = S

FD 38 R = H, R' = t-Bu, X = S

FD 39 R = t-Bu, R' = H, X = S

FD 40 R = R' = t-Bu, X = S

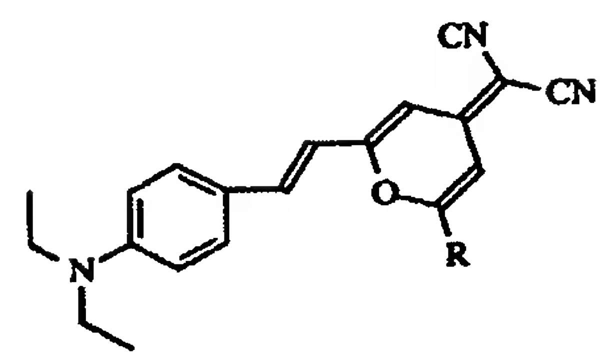


FD 41 R = phenyl

FD 42 R = Me

FD 43 R = t-Bu

FD 44 R = mesityl

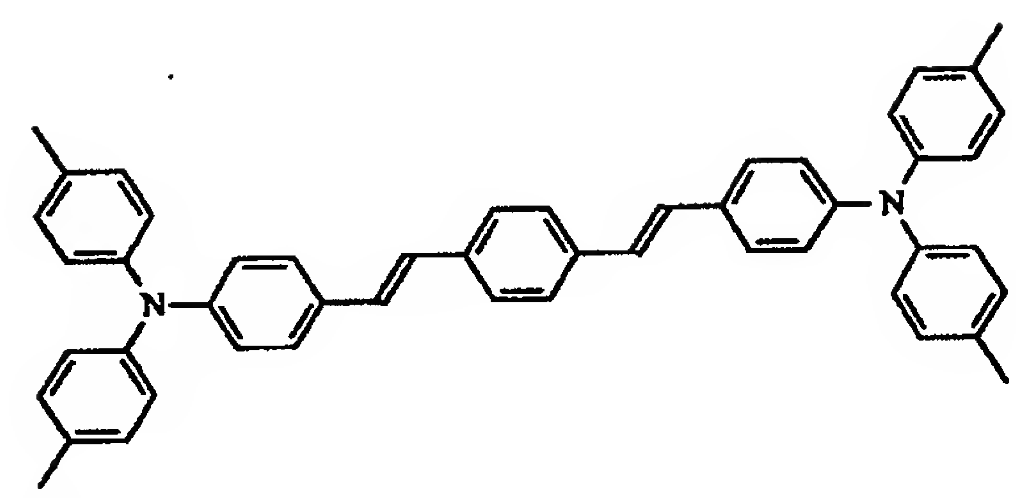


FD 45 R = phenyl

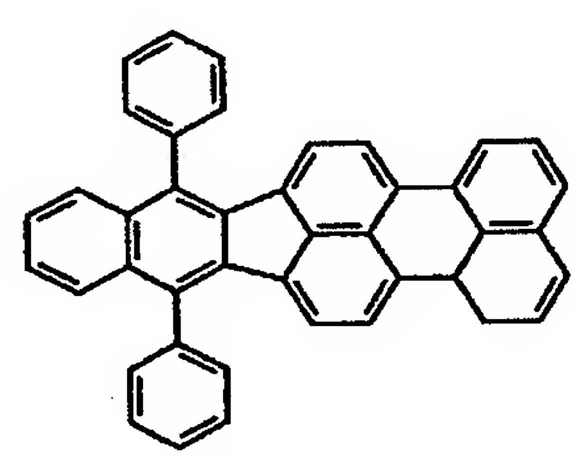
FD 46 R = Me

FD 47 R = t-Bu

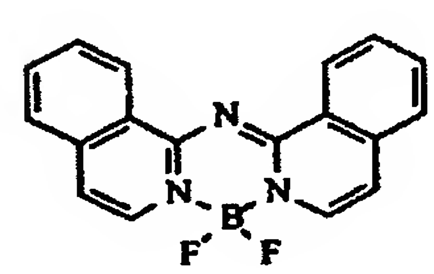
FD 48 R = mesityl



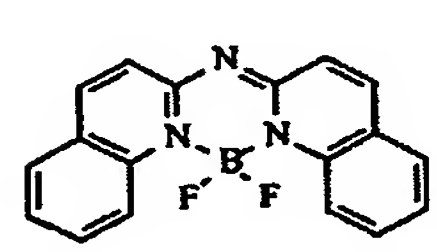
FD 49



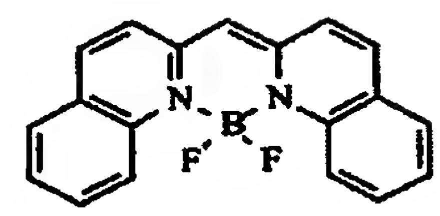
FD 50



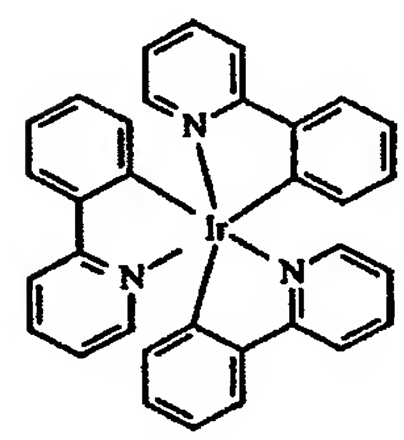
FD 51



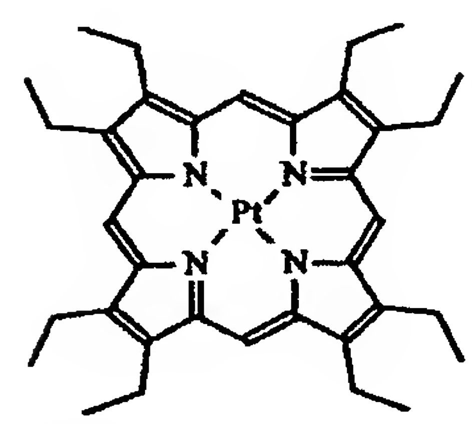
FD 52



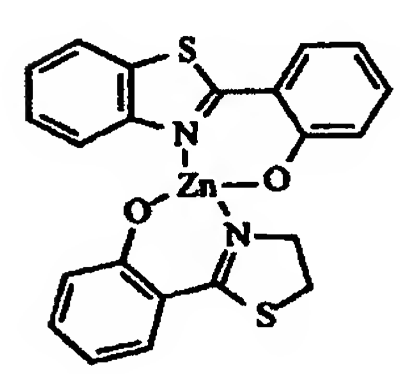
FD 53



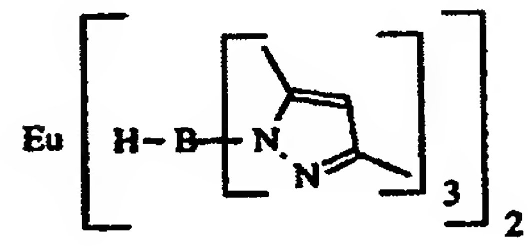
PD 1



PD 2



PD 3



PD 4

Electron-Transporting Layer (ETL):

Preferred thin film-forming materials for use in forming the electron-transporting layer 111 of the organic EL devices of this invention are metal chelated oxinoid compounds, including chelates of oxine itself (also commonly referred to as 8-quinolinol or 8-hydroxyquinoline). Such compounds help to inject and transport electrons and exhibit both high levels of performance and are readily fabricated in the form of thin films. Exemplary of contemplated oxinoid compounds are those satisfying structural formula (E), previously described.

Other electron-transporting materials include various butadiene derivatives as disclosed in US-A-4,356,429 and various heterocyclic optical brighteners as described in US-A-4,539,507. Benzazoles satisfying structural formula (G) are also useful electron transporting materials. Triazines are also known to be useful as electron transporting materials. Oxadiazole compounds including small molecules and polymers are useful electron transporting materials as described in US-A-6,451,457.

Cathode:

When light emission is viewed solely through the anode, the cathode 113 used in this invention can be comprised of nearly any conductive material. Desirable materials have good film-forming properties to ensure good contact with the underlying organic layer, promote electron injection at low voltage, and have good stability. Useful cathode materials often contain a low work function metal (< 4.0 eV) or metal alloy. One preferred cathode material is comprised of a Mg:Ag alloy wherein the percentage of silver is in the range of 1 to 20 %, as described in commonly-assigned US-A-4,885,211. Another suitable class of cathode materials includes bilayers comprising a thin electron-injection layer (EIL) in contact with the organic layer (for example, ETL) which is capped with a thicker layer of a conductive metal. Here, the EIL preferably includes a low work function metal or metal salt, and if so, the thicker capping layer does not need to have a low work function. One such cathode is comprised of a thin layer of LiF followed by a thicker layer of Al as described in commonly-assigned

US-A-5,677,572. Other useful cathode material sets include, but are not limited to, those disclosed in commonly-assigned US-A-5,059,861; US-A-5,059,862, and US-A-6,140,763.

When light emission is viewed through the cathode, the cathode must be transparent or nearly transparent. For such applications, metals must be thin or one must use transparent conductive oxides, or a combination of these materials. Optically transparent cathodes have been described in more detail in US-A-4,885,211; US-A-5,247,190; US-A-5,703,436; US-A-5,608,287; US-A-5,837,391; US-A-5,677,572; US-A-5,776,622; US-A-5,776,623; US-A-5,714,838; US-A-5,969,474; US-A-5,739,545; US-A-5,981,306; US-A-6,137,223; US-A-6,140,763; US-A-6,172,459; US-A-6,278,236; US-A-6,284,3936; EP 1 076 368 and JP 3,234,963. Cathode materials are typically deposited by evaporation, sputtering, or chemical vapor deposition. When needed, patterning can be achieved through many well known methods including, but not limited to, through-mask deposition, integral shadow masking as described in US-A-5,276,380 and EP 0 732 868, laser ablation, and selective chemical vapor deposition.

Other Useful Organic Layers and Device Architecture

In some instances, layers 109 and 111 can optionally be collapsed into a single layer that serves the function of supporting both light emission and electron transportation. Alternatively, layers 107, 109 and 111 can optionally be collapsed into a single layer that serves the function of supporting both light emission and hole and electron transportation. This is the preferred EL device structure of this invention and is referred to as "single-layer" device.

It also known in the art that emitting dopants may be added to the hole-transporting layer, which may serve as a host. Multiple dopants may be added to one or more layers in order to create a white-emitting EL device, for example, by combining blue- and yellow-emitting materials, cyan- and red-emitting materials, or red-, green-, and blue-emitting materials. White-emitting devices are described, for example, in EP 1 187 235, EP 1 182 244,

U.S. Patent Publication 20020025419, and US-A-5,683,823; US-A-5,503,910; US-A-5,405,709; and US-A-5,283,182.

Additional layers such as electron or hole-blocking layers as taught in the art may be employed in devices of this invention. Hole-blocking layers are commonly used to improve efficiency of phosphorescent emitter devices, for example, as in U.S. Patent Publication 20020015859.

This invention may be used in so-called stacked device architecture, for example, as taught in US-A-5,703,436 and US-A-6,337,492.

Deposition of organic layers

The organic materials mentioned above can be deposited as high quality transparent thin films by various methods such as a vapor deposition or sublimation method, an electron-beam method, a sputtering method, a thermal transferring method, a molecular lamination method and a coating method such as solution casting, spin-coating or inkjet printing, with an optional binder to improve film formation. If the material is a polymer, solvent deposition is usually preferred. The material to be deposited by sublimation can be vaporized from a sublimator "boat" often comprised of a tantalum material, for example, as described in US-A-6,237,529, or can be first coated onto a donor sheet and then sublimed in closer proximity to the substrate. Layers with a mixture of materials can utilize separate sublimator boats or the materials can be pre-mixed and coated from a single boat or donor sheet. Patterned deposition can be achieved using shadow masks, integral shadow masks (US-A-5,294,870), spatially-defined thermal dye transfer from a donor sheet (US-A-5,688,551; US-A-5,851,709 and US-A-6,066,357) and inkjet method (US-A-6,066,357).

Preferably, the spin-coating or inkjet printing technique is used to deposit the organic material of the invention, only one compound is deposited in a single layer device.

Encapsulation:

Most organic EL devices are sensitive to moisture or oxygen, or both, so they are commonly sealed in an inert atmosphere such as nitrogen or argon, along with a desiccant such as alumina, bauxite, calcium sulfate, clays,

silica gel, zeolites, alkaline metal oxides, alkaline earth metal oxides, sulfates, or metal halides and perchlorates. Methods for encapsulation and desiccation include, but are not limited to, those described in US-A-6,226,890. In addition, barrier layers such as SiOx, Teflon, and alternating inorganic/polymeric layers are known in the art for encapsulation.

Optical Optimization:

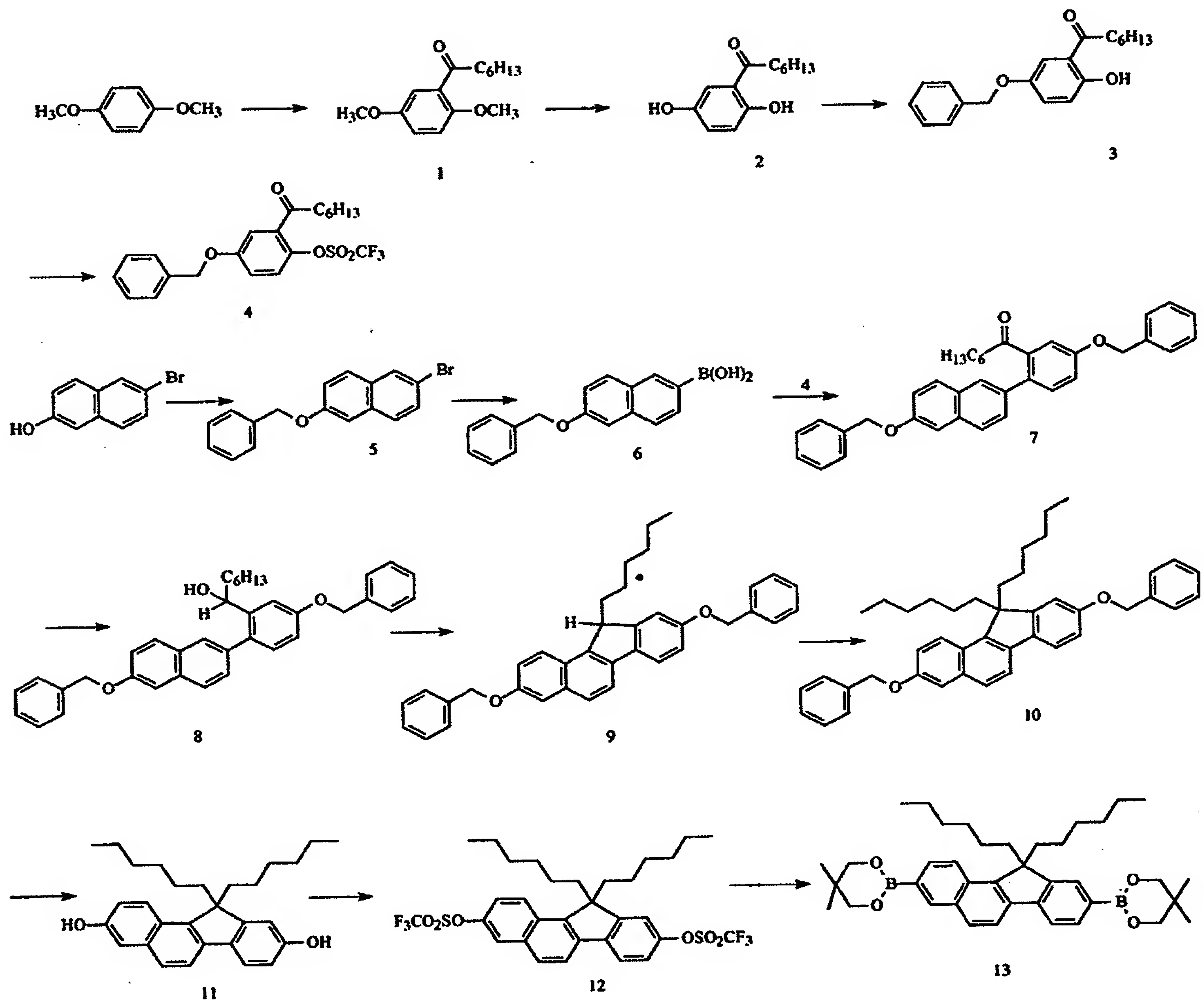
Organic EL devices of this invention can employ various well-known optical effects in order to enhance its properties if desired. This includes optimizing layer thicknesses to yield maximum light transmission, providing dielectric mirror structures, replacing reflective electrodes with light-absorbing electrodes, providing anti glare or anti-reflection coatings over the display, providing a polarizing medium over the display, or providing colored, neutral density, or color conversion filters over the display. Filters, polarizers, and anti-glare or anti-reflection coatings may be specifically provided over the cover or as part of the cover.

EXAMPLES

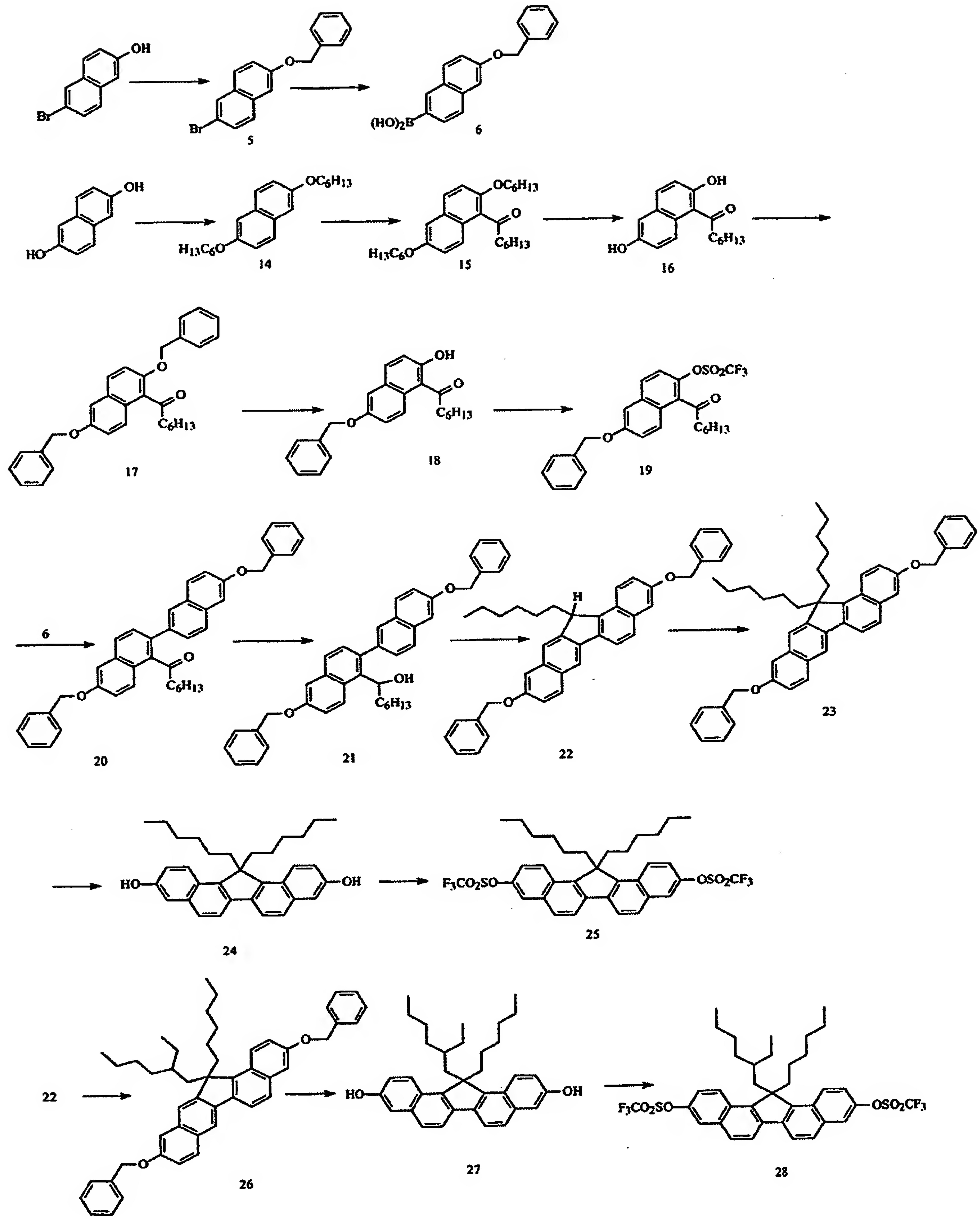
The invention and its advantages are further illustrated by the following specific examples:

Synthesis of Small Molecules

The monomers to be used in the present invention to construct polymers are not necessary to be particularly restricted. Any monomers can be used as long as the polymer formed is a polymer which satisfies the general formulas (V) and (VI). Typical synthesis is illustrated in Schemes 1-11.

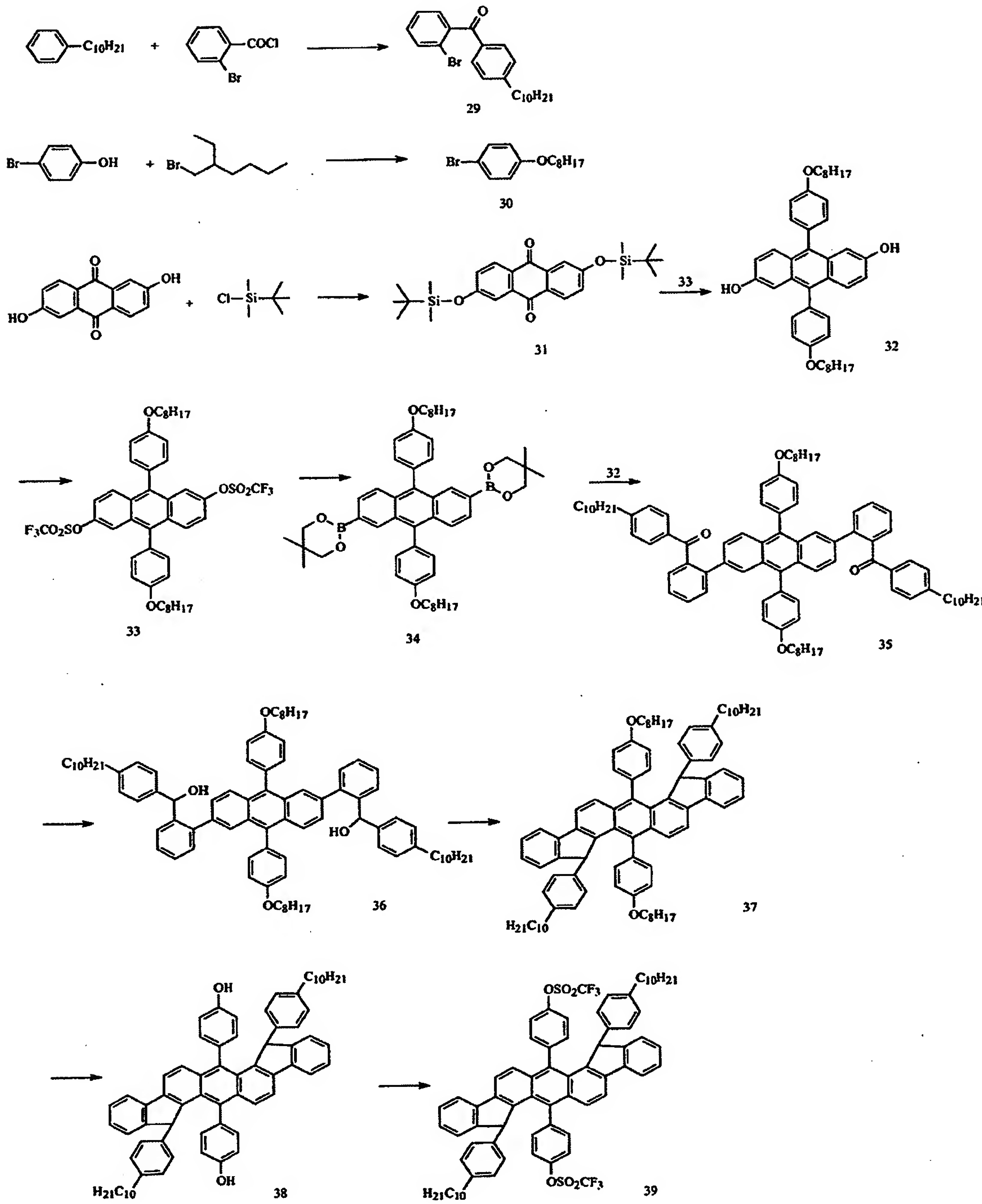


Scheme 1

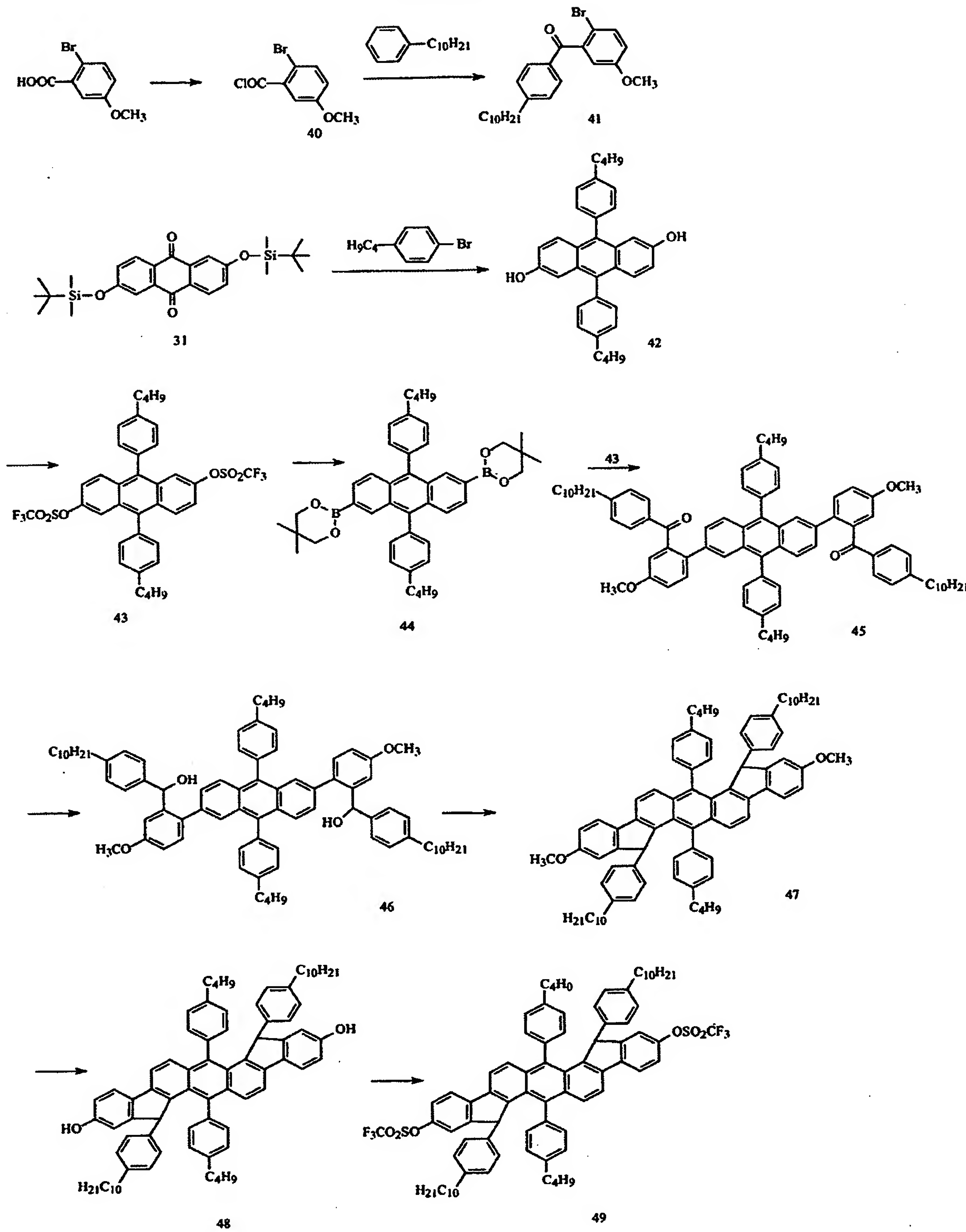


OH
Br
5
(HO)2B
6
HO
OC6H13
H13C6O
14
15
O
C6H13
16
17
18
OSO2CF3
19
20
OH
21
H
22
23
24
F3CO2SO
25
26
27
28

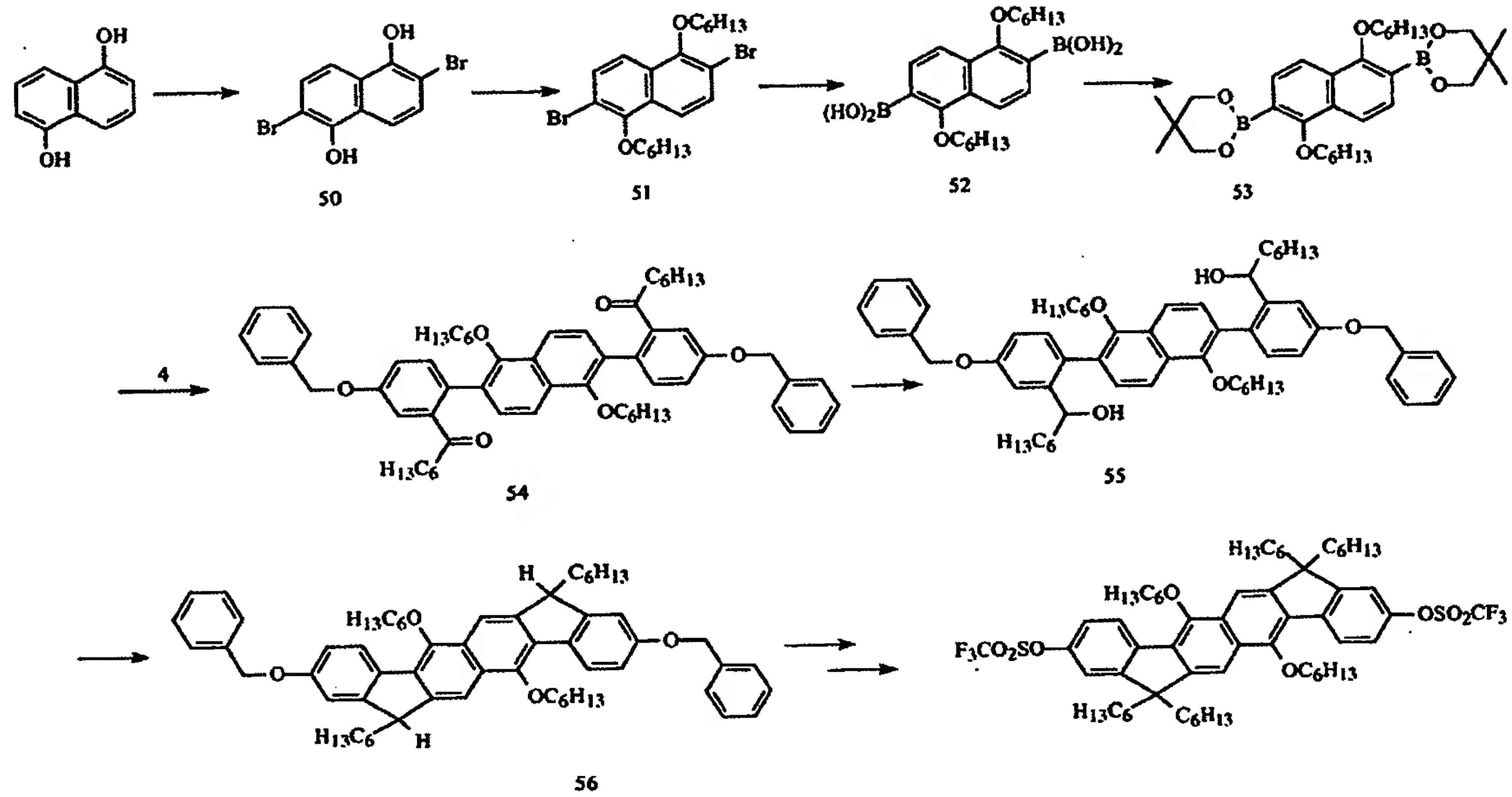
Scheme 2


C10H21
COCl
Br
29
Br
OH
OC8H17
30
Cl
Si
O
31
33
HO
32
OSO2CF3
F3CO2SO
34
35
36
37
38
39

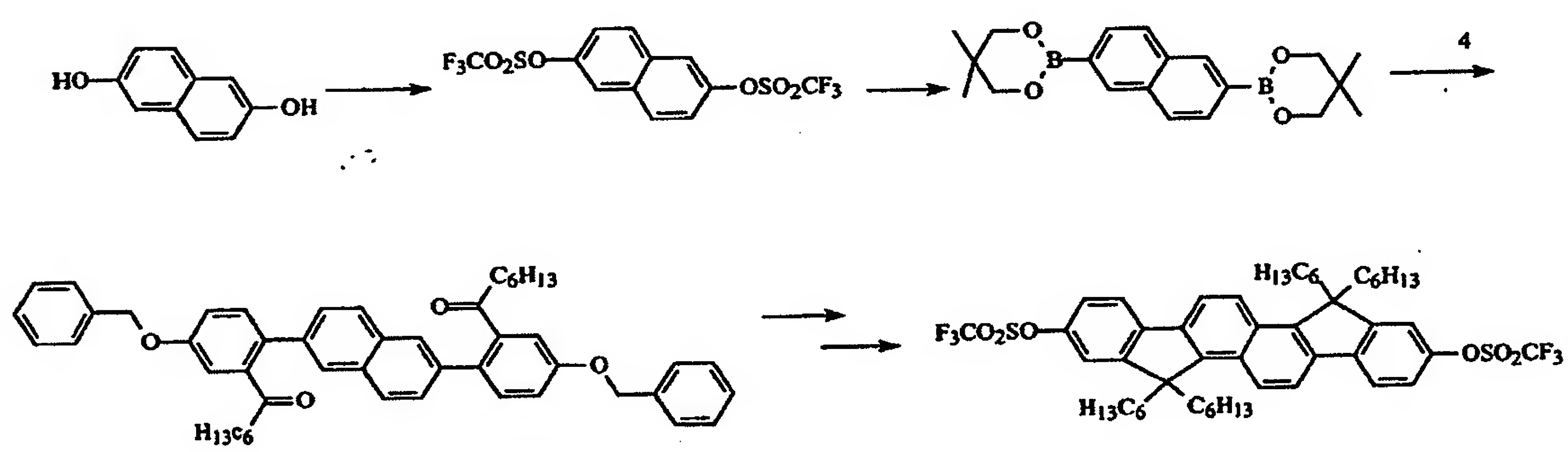
Scheme 3


Br
HOOC
OCH3
ClOC
40
C10H21
41
31
H9C4
42
C4H9
OH
HO
OSO2CF3
F3CO2SO
43
44
45
46
47
48
49
H3CO
H21C10

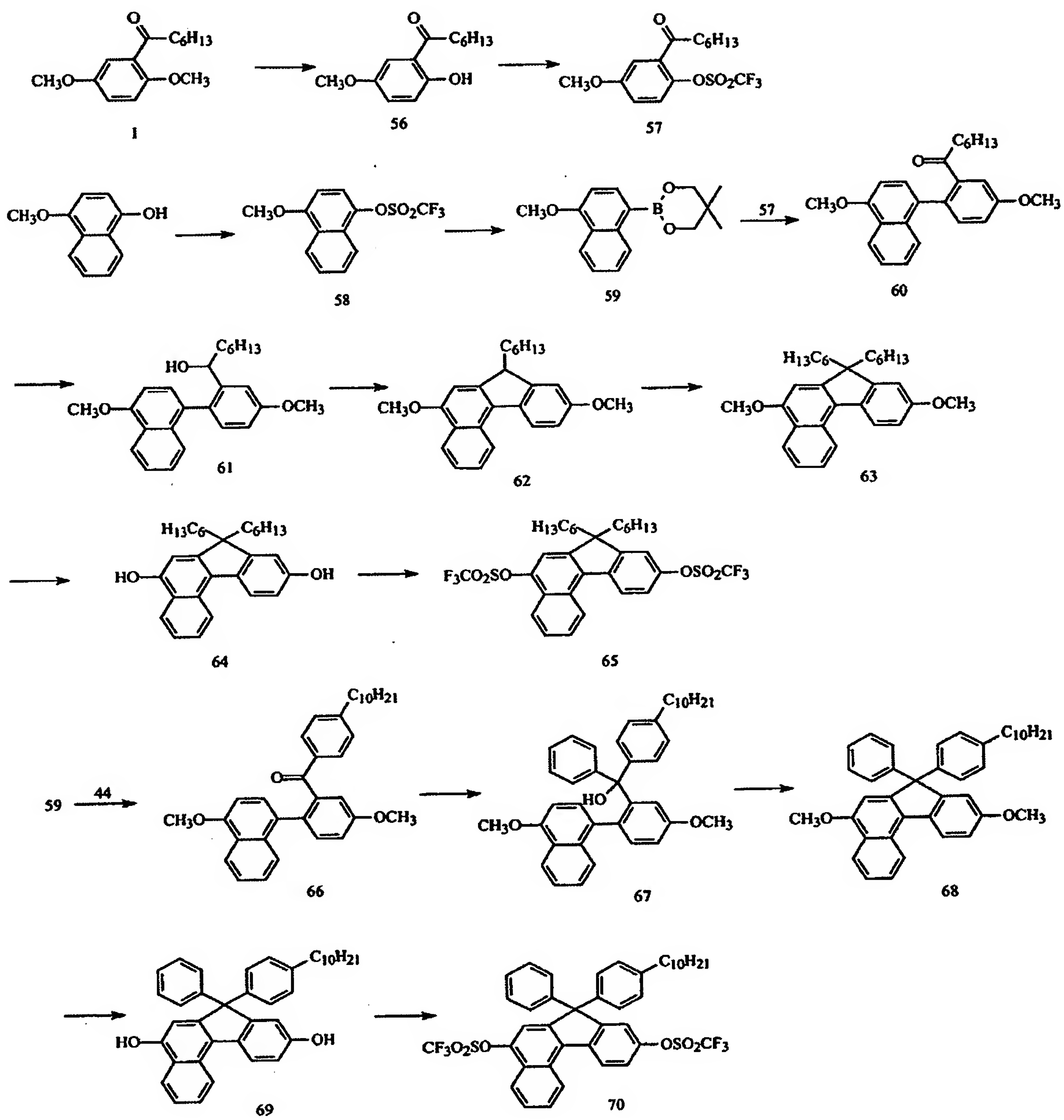
Scheme 4



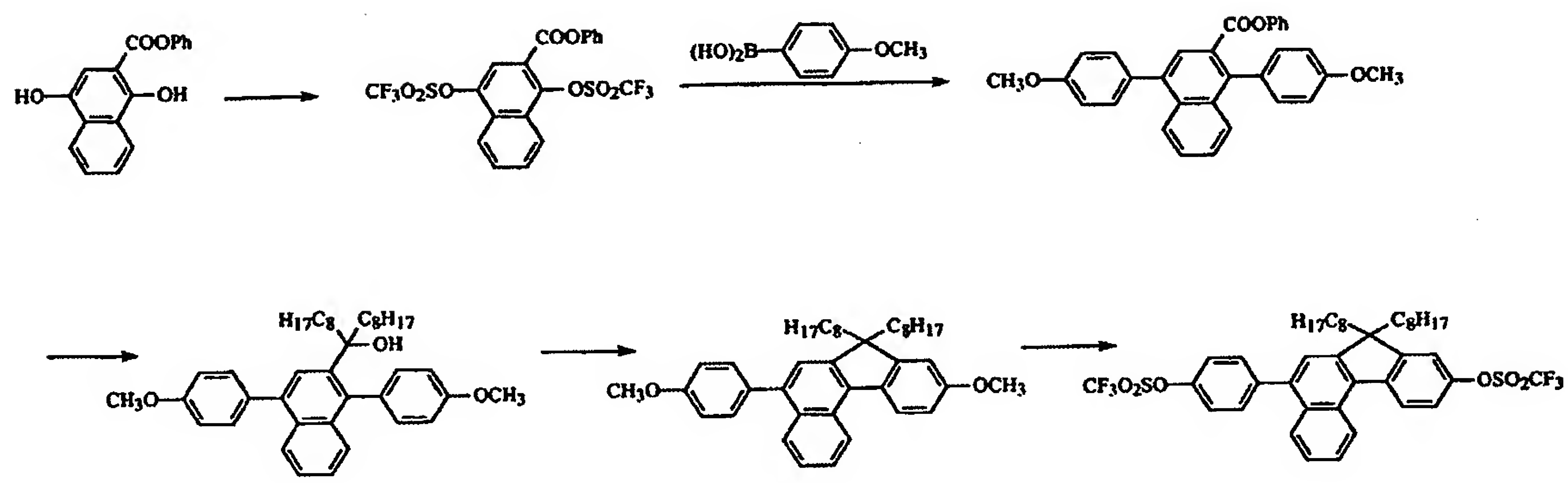
Scheme 5



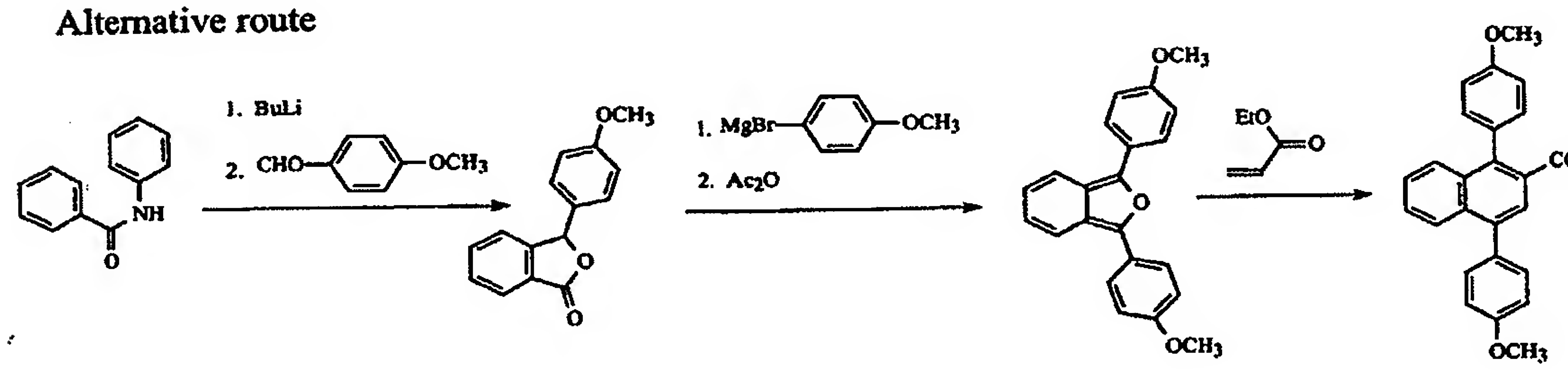
Scheme 6



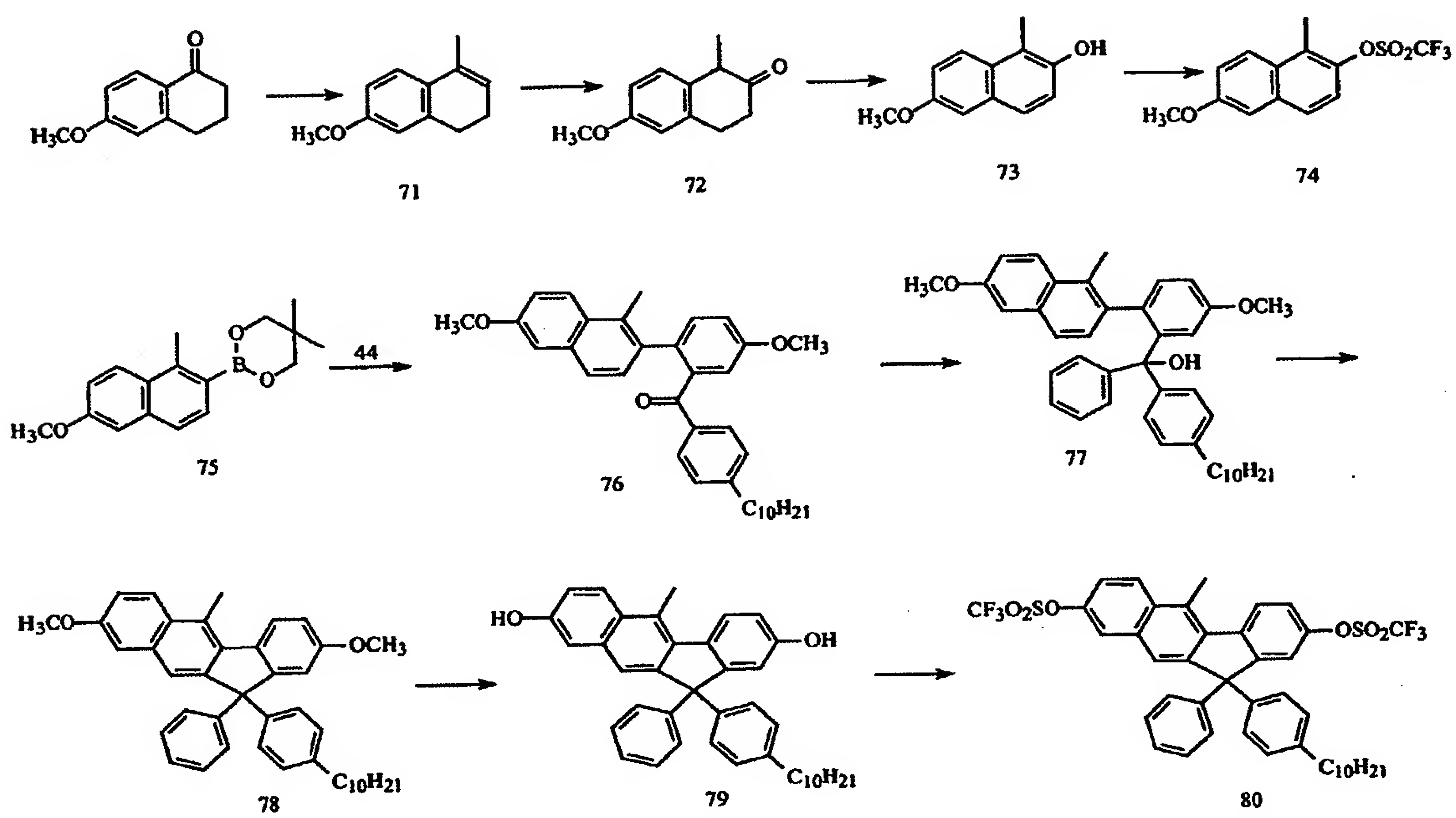
Scheme 7



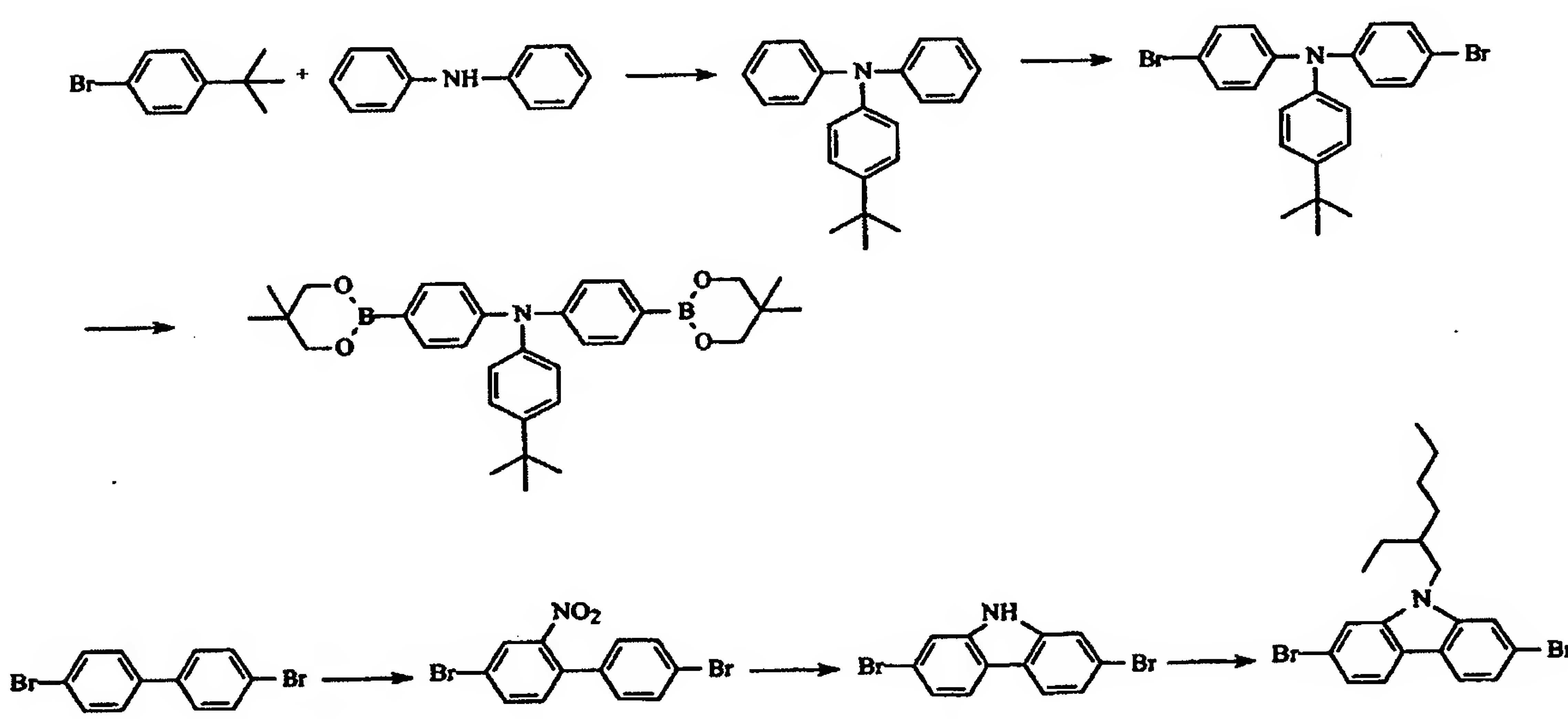
Alternative route



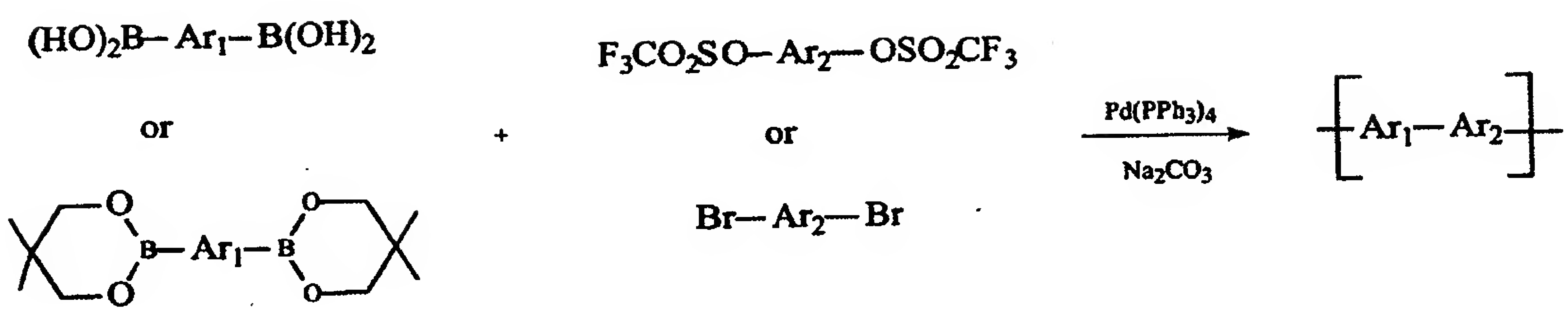
Scheme 8



Scheme 9



Scheme 10



Scheme 11

Example 1: synthesis of compound 1 (2,5-dimethoxy-heptanophenone)

1,4-Dimethoxybenzene (15.0 g, 0.11 mol) was dissolved in 100 mL of methylene chloride and the solution was cooled to 0 °C. To the solution was added aluminum chloride (17.37 g, 0.13 mol) in portions and the mixture was stirred for 10 min. Heptanoyl chloride (17.75 g, 0.12 mol) was added via an additional funnel. After 2 h, reaction was complete and was quenched with dilute HCl solution carefully. The organic phase was separated, washed with dilute sodium bicarbonate, and dried over magnesium sulfate. The crude product was purified by column on silica gel using either/heptane (10/90) as an eluent to give 20.52 g pure product as clear oil (75% yield). FD-MS: 250 (M^+).

Example 2: synthesis of compound 2 (2,5-dihydroxy-heptanophenone)

Compound 1 (10.0 g, 0.040 mol) was dissolved in 150 mL of toluene. To this solution was added aluminum chloride (11.72 g, 0.088 mol) in portions. The reaction was heated to 80 °C overnight. After cooled to room temperature, the reaction was poured into dilute HCl solution. The organic phase was separated and the aqueous phase was extracted with methylene chloride. The combined organic phase was dried over magnesium sulfate. The crude product was purified by recrystallization from hexane/ethyl acetate to give 6.42 g of pure product as yellow fluffy solid (72% yield). ^{1}H NMR ($CDCl_3$) δ ppm: 0.89 (t, J =6.6 Hz, 3 H), 1.28-1.39 (m, 6 H), 1.67-1.76 (m, 2 H), 2.91 (t, J = 7.5 Hz, 2 H), 5.37 (br, 1 H), 6.87 (d, J = 8.9 Hz, 1 H), 7.03 (dd, J_1 = 8.9 Hz, J_2 = 3.0 Hz, 1 H), 7.22 (d, J = 3.0 Hz, 1 H), 12.06 (s, 1 H); FD-MS: 222 (M^+).

Example 3: synthesis of compound 3 (5-benyloxy2-hydroxy-heptanophenone)

Compound 2 (53.60 g, 0.24 mol) was dissolved in 500 mL of acetone. To this solution was added anhydrous potassium carbonate (36.66 g, 0.26 mol). The mixture was stirred for 10 min and benzyl bromide (45.37 g, 0.26 mol) was added dropwise. The reaction was refluxed overnight. After cooled to room temperature, the reaction was filtered and acetone was evaporated. The residue was extracted with ether and dried over magnesium sulfate. The crude product was purified by column on silica gel using heptane/ethyl acetate (98/2) as an eluent. The product was obtained as light yellow solid after further recrystallization from heptane, 50.12 g (0.67% yield). ^{1}H NMR ($CDCl_3$) δ ppm:0.90 (t, J = 6.6 Hz, 3 H), 1.32-1.39 (m, 6 H), 1.64-1.71 (m, 2 H), 2.88 (t, J =7.5 Hz, 2 H), 5.03 (s, 2 H), 6.91 (d, J =9.0 Hz, 1 H), 7.15 (dd, J_1 = 9.0 Hz, J_2 = 3.0 Hz, 1 H), 7.25 (d, J = 3.0 Hz, 1 H), 7.32-7.43 (m, 5 H), 11.99 (s, 1 H); FD-MS: 222 (M^+).

Example 4: synthesis of compound 4

Compound 3 (50.0 g, 0.16 mol) was dissolved in methylene chloride and cooled to 0 °C. To the solution was added triethylamine (19.4 g, 0.19 mol), followed by slow addition of triflate anhydride (54.2 g, 0.19 mol). The mixture was stirred at room temperature for a few hours until the completion of the reaction. The reaction was quenched with water, extracted with methylene chloride and dried over $MgSO_4$. The crude product was recrystallized passed through a short pad of silica gel and recrystallized from heptane to give 55.0 g pure product as fluffy white powder (77% yield). FD-MS: 444 (M^+).

Example 5: synthesis of compound 5 (2-bromo-6-benzyloxynaphthalene)

6-Bromo-2-naphthol (50.0 g, 0.22 mol) was dissolved in 150 mL of DMF, and potassium carbonate (123.92 g, 0.90 mol) was added. The mixture was stirred for 10 min and benzyl bromide (95.84 g, 0.56 mol) was added. The reaction mixture was heated at 90 °C for 4 h and poured into water. The crude product was collected as yellow powder and was purified by recrystallization from ethanol to give 68.05 g pure product as sparklingly white needles (97% yield). ^{1}H NMR ($CDCl_3$) δ ppm: 5.17 (s, 2 H), 7.18 (d, J= 2.4 Hz, 1 H), 7.25 (dd, J_1 = 8.9

Hz, J_2 = 2.5 Hz, 1 H), 7.35-7.52 (m, 6H), 7.60 (d, J = 8.8 Hz, 1 H), 7.67 (d, J = 8.9 Hz, 1 H), 7.92 (d, J = 1.6 Hz, 1 H); ^{13}C NMR ($CDCl_3$): 70.08, 107.09, 109.74, 117.15, 120.08, 127.56, 128.11, 128.42, 128.55, 128.64, 129.62, 130.09, 132.96, 136.57; FD-MS: 313 (M^+).

Example 6: synthesis of compound 6 (6-benzyloxy-2-naphalene boronic acid)

Compound 5 (15.65 g, 0.050 mol) was dissolved in 200 mL of anhydrous THF and cooled to –78 °C. To the cold solution was added dropwise n-BuLi (30 mL, 2.5 M in hexane, 0.075 mol) to maintain the temperature lower than –60 °C. After one hour, trimethylborate (10.39 g, 0.10 mol) was added and the reaction was stirred for 3 h. The reaction was quenched by dilute HCl, stirred at room temperature for 1 h, and extracted with methylene chloride. The organic phase was dried over $MgSO_4$ and concentrated. The crude product was recrystallized from toluene to give light gray solid that was recrystallized again in methanol to remove the insoluble by-product. The pure product was concentrated from the filtrate as white solid, 6.1 g (44% yield). FD-MS: 278(M^+).

Example 7: synthesis of compound 7

Compound 4 (24.16 g, 0.054 mol) and compound 6 (13.60 g, 0.049 mol) were dissolved in 100 mL of toluene and 2 M solution of Na_2CO_3 (36 mL, 0.072 mol) and a few drops of phase transfer reagent Aquat 336 were added. The mixture was bubbled with nitrogen for 10 min and catalyst tetrakis(triphenylphosphine) palladium (0.85 g, 1.5 mol%) was added. The reaction was heated to 105 °C for 3 h. After cooled down, the organic phase was separated and the aqueous phase was extracted with methylene chloride. The combined organic phase was dried over $MgSO_4$. The crude product was recrystallized twice from heptane to give 15.13 g of pure product as white powder (58% yield). ^{1}H NMR ($CDCl_3$) δ ppm:0.73 (t, J = 7.2 Hz, 3 H), 0.92-0.97 (m, 4 H), 1.04-1.10 (m, 2 H), 1.35-1.40 (m, 2 H), 2.22 (t, J = 7.4 Hz, 2 H), 5.15 (s, 2 H), 5.21 (s, 2 H), 7.11-7.16 (m, 2 H), 7.26-7.52 (m, 14 H), 7.67 (d, J = 1.3 Hz, 1 H), 7.76 (d, J = 8.4 Hz, 2 H); ^{13}C NMR ($CDCl_3$): 14.04, 22.36, 24.56, 28.59, 31.35, 42.92, 70.06, 70.24, 106.87, 113.39, 117.12, 119.62, 127.12, 127.31, 127.37,

127.44, 127.96, 128.01, 128.53, 128.83, 129.51, 131.51, 135.40, 136.61, 142.18, 156.89, 157.82, 208.15; FD-MS: 528 (M^+).

Example 8: synthesis of compound 8

Compound 7 (11.20 g, 0.021 mol) was dissolved in 100 mL of anhydrous THF and cooled to 0 °C. LAH (1.60 g, 0.042 mol) was added in portions under nitrogen. After addition, the reaction was stirred for 15 min, and quenched with sodium sulfate decahydrate carefully. The reaction was filtered and the precipitated solid was washed methylene chloride. The filtrate was concentrated to give pure product at quantitative yield, 11.35 g. ^{1}H NMR ($CDCl_3$) δ ppm: 0.78 (t, J = 7.1 Hz, 3 H), 1.11-1.69 (m, 10 H), 4.81-4.85 (m, 1 H, OH), 5.15 (s, 2 H), 5.21 (s, 2 H), 6.96 (dd, J_1 = 8.5 Hz, J_2 = 2.6 Hz, 2 H), 7.20-7.52 (m, 14 H), 7.65 (s, 1H), 7.73 (d, J = 2.2 Hz, 1 H), 7.73-7.77 (m, 1 H); ^{13}C NMR ($CDCl_3$): 14.00, 22.50, 25.81, 28.95, 31.60, 38.76, 70.07, 70.48, 106.97, 109.76, 111.76, 113.77, 119.47, 126.49, 127.55, 127.98, 128.03, 128.54, 128.59, 128.63, 128.79, 129.46, 131.37, 133.26, 133.54, 136.82, 143.92, 156.84; FD-MS: 530 (M^+).

Example 9: synthesis of compound 9

Compound 8 (14.10 g, 0.028 mol) was dissolved in 100 mL of methylene chloride and cooled to 0 °C. To the solution was added boron trifluoride etherate (5.9 g, 0.042 mol). After 20 min, the reaction was quenched carefully with saturated sodium bicarbonate solution. Organic phase was separated and the aqueous phase was extracted with methylene chloride. The combined organic phase was dried over $MgSO_4$. The crude product was recrystallized from heptane twice to give 8.21 g of product as off-white solid (56% yield). ^{1}H NMR ($CDCl_3$) δ ppm: 0.72 (t, J = 7.1 Hz, 3 H), 0.80-0.83 (m, 2 H), 1.03-1.12 (m, 6 H); 2.02-2.14 (m, 1 H), 2.17-2.27 (m, 1 H), 4.26-4.29 (m, 1 H), 5.10 (s, 2 H), 5.14 (s, 2 H), 6.96 (dd, J_1 =8.3 Hz, J_2 = 2.2 Hz, 1 H), 7.16-7.47 (m, 14 H), 7.59 (d, J = 8.3 Hz, 1 H), 7.65-7.73 (m, 2 H), 7.93 (d, J = 8.7 Hz, 1 H); ^{13}C NMR ($CDCl_3$): 14.00, 22.57, 24.41, 29.52, 31.52, 33.66, 47.10, 70.03, 70.40, 108.66, 111.51, 113.19, 118.79, 119.16, 119.70, 125.36, 126.83, 127.56, 127.60,

127.94,128.01, 128.57, 128.61, 133.82, 135.35, 136.64, 136.93, 137.15, 142.34, 149.97, 155.86, 157.93; FD-MS: 512 (M^+).

Example 10: synthesis of compound 10

Compound 9 (8.20 g, 0.016 mol) was suspended in 16 mL of DMSO and the mixture was degassed by bubbling with nitrogen for 10 min. To this mixture was added 3 drops of phase transfer reagent Aquat® 336 and 50% NaOH aqueous solution (2.56 g, 0.032 mol) under nitrogen. The reaction turned bright orange immediately. n-Hexylbromide (3.20 g, 0.019 mol) was then added dropwise and the reaction was heated to 80 °C. The orange color disappeared and reaction became light yellow and clear. After 20 min, the reaction was poured into water and extracted with ether. The combined organic phase was washed with water and dried over $MgSO_4$. After the removal of the solvent, the pure product was obtained as light brownish-yellow oil (quantitative yield). ^1H NMR ($CDCl_3$) δ ppm: 0.44-0.52 (m, 4 H), 0.76 (t, J = 7.1 Hz, 6 H), 0.94-1.12 (m, 12 H), 2.13-2.23 (m, 2 H), 2.42-2.52 (m, 2H), 5.21 (s, 2 H), 5.24 (s, 2 H), 7.05 (dd, J_1 = 8.2 Hz, J_2 = 2.3 Hz, 1 H), 7.11 (d, J =2.1 Hz, 1 H), 7.33-7.58 (m, 14 H), 7.68 (d, J = 8.2 Hz, 1 H), 7.76-7.84 (m, 2 H), 8.16 (d, J = 9.2 Hz); ^{13}C NMR ($CDCl_3$): 13.94, 22.50, 23.50, 29.54, 31.31, 40.52, 57.22, 69.97, 70.35, 108.93, 109.42, 112.98, 118.68, 118.82, 119.41, 124.78, 125.97, 127.01, 127.62, 127.91, 127.99, 128.52, 128.58, 134.22, 135.02, 136.94, 137.01, 137.09, 143.56, 153.66, 155.55, 158.24; FD-MS: 596 (M^+).

Example 11: synthesis of compound 11

Compound 10 (9.55 g, 0.016 mol) was dissolved in 100 mL of methylene chloride and was cooled to 0 °C. To this solution was added boron tribromide (6.05g, 0.024 mol) dropwise. After 30 min, the reaction was quenched with saturated sodium bicarbonate. The aqueous layer was extracted with methylene chloride and the combined organic layer was washed with water and dried over $MgSO_4$. The crude product was washed with minimum amount of methylene chloride to 4.21 g give pure product as light tan solid and the filtrate was purified by column chromatography on silica gel to give 1.42 g of product (total yield 84%). ^1H NMR ($CDCl_3$) δ ppm: 0.34-0.47 (m, 4 H), 0.69 (t, J = 7.0

Hz, 6 H), 0.90-1.05 (m, 12 H), 2.05-2.13 (m, 2 H), 2.33-2.43 (m, 2 H), 4.78 (br, 1 H), 4.93 (br, 1 H), 6.82 (dd, J_1 = 8.1 Hz, J_2 = 2.3 Hz, 1 H), 6.90 (d, J = 2.2 Hz, 1 H), 7.15 (J_1 = 9.0 Hz, J_2 = 2.3 Hz, 1 H), 7.24 (d, J = 2.4 Hz, 1 H), 7.57 (d, J = 8.0 Hz, 1 H), 7.67 (d, J = 8.2 Hz, 1 H), 7.75 (d, J = 8.4 Hz, 1 H), 8.06 (d, J = 9.1 Hz, 1 H); ^{13}C NMR ($CDCl_3$): 13.93, 22.50, 23.51, 29.55, 31.34, 40.53, 109.45, 109.75, 111.37, 113.78, 117.60, 118.85, 118.88, 119.61, 125.09, 126.58, 128.80, 128.80, 134.92, 143.47, 152.08, 154.80; FD-MS: 416 (M^+).

Example 12: synthesis of compound 12

Compound 11 (5.60 g, 0.013 mol) and triethylamine (3.56 g, 0.035 mol) were dissolved in 80 mL of methylene chloride, and the solution was cooled to 0 °C. Triflate anhydride (9.10 g, 0.032 mol) was added slowly. After 30 min, the reaction was quenched by water, and the aqueous phase was extracted with methylene chloride. The combined organic phase was washed with water and dried over $MgSO_4$. The crude product was recrystallized from heptane to give 7.12 g of pure product as light cream needles (79% yield). ^{1}H NMR ($CDCl_3$) δ ppm: 0.30-0.40 (m, 4H), 0.69 (t, J = 6.9 Hz, 6 H), 0.88-1.04 (m, 12 H), 2.17-2.67 (m, 2 H), 2.38-2.48 (m, 2 H), 7.31-7.34 (m, 2 H), 7.48 (dd, J_1 = 9.2 Hz, J_2 = 2.5 Hz, 1 H), 7.83 (d, J = 8.2 Hz, 1 H), 7.87 (d, J = 2.5 Hz, 1 H), 7.91-7.98 (m, 2 H), 8.25 (d, J = 9.3 Hz, 1 H); ^{13}C NMR ($CDCl_3$): 13.80, 22.32, 23.40, 29.22, 31.15, 40.03, 58.08, 115.56, 120.12, 120.23, 120.27, 120.76, 120.98, 125.93, 128.91, 129.10, 133.98, 138.58, 140.81, 145.08, 146.56, 149.20, 154.48; FD-MS: 680 (M^+).

Example 13: synthesis of compound 13

Compound 12 (1.81 g, 0.003 mol), bis(neopentyl glycola)diboron (1.31 g, 0.006 mol) and potassium acetate (1.55 g, 0.016 mol) were mixed in 15 mL of dioxane. The mixture was bubbled with nitrogen for 5 min and catalyst bis(diphenylphosphino)ferrocene palladium chloride ($Pd(dppf)_2Cl_2$) (70 mg, 0.03 mol%) and ligand dppf (40 mg, 0.03 mol%) were added. The reaction was heated at 80 °C under nitrogen overnight. The reaction was extracted with methylene chloride and water, and the crude product was passed through a short column of silica gel to give 1.31 g of pure product as light yellow foam (82% yield).

^{1}H NMR ($CDCl_3$): 0.26-0.40 (m, 4 H), 0.66 (t, J = 7.0 Hz, 6 H), 0.83-0.98 (m, 12 H), 1.07 (s, 12 H), 2.21-2.31 (m, 2 H), 2.42-2.52 (m, 2 H), 3.83 (s, 4 H), 3.84 (s, 4 H), 7.75 (d, J = 8.8 Hz, 1 H), 7.83 (d, J = 8.4 Hz, 1 H), 7.85-7.92 (m, 4 H), 8.18 (d, J = 8.5 Hz, 1 H), 8.44 (s, 1 H); ^{13}C NMR ($CDCl_3$): 13.91, 21.95, 22.04, 22.49, 23.48, 29.54, 31.31, 31.92, 31.97, 40.09, 57.31, 72.35, 72.44, 109.77, 118.47, 122.62, 127.10, 129.00, 130.06, 131.75, 132.61, 133.18, 136.64, 139.72, 144.00, 144.78, 151.40; FD-MS: 608 (M^+).

Example 14: synthesis of compound 14 (2,6-dihexyloxynaphthalene)

2,6-Dihydroxynaphthalene (30.0 g, 0.19 mol) reacted with n-hexylbromide (68.06 g, 0.41 mol) in the presence of potassium carbonate (129.6 g, 0.94 mol) in 400 mL of DMF at 95 °C for 3h. The reaction was poured into 700 mL of water and the precipitate was filtered, washed with water and methanol, and dried. The crude product was recrystallized from ethanol to give 54.5 g (88% yield) of pure product white crystals. ^{1}H NMR $CDCl_3$) δ (ppm): 0.91 (t, J = 6.9 Hz, 6 H), 1.32-1.40 (m, 8H), 1.44-1.54 (m, 4H), 1.77-2.86 (m, 4H), 4.02 (t, J = 6.6 Hz, 4H), 7.06-7.12 (m, 4H), 7.60 (d, J = 8.8 Hz, 2H); M.p. 78-79 °C; FD-MS: 328 (M^+).

Example 15: synthesis of compound 15

Compound 14 (25.5 g, 0.078 mol) was dissolved in 250 mL of methylene chloride and cooled to 0 °C. To this solution was added aluminum chloride (12.7 g, 0.085 mol) in portions and heptanoyl chloride (12.4 g, 0.093 mol) was added via an additional funnel. The reaction was monitored by TLC and was quenched carefully with 2N HCl solution. The reaction was extracted with methylene chloride and the combined organic phase was dried over $MgSO_4$. The crude product was recrystallized from heptane to give 25.4 g (74% yield) as light yellow powder. ^{1}H NMR $CDCl_3$) δ (ppm): 0.77-0.85 (m, 9 H), 1.21-1.39 (m, 18 H), 1.61-1.76 (m, 6 H), 2.84 (t, J = 7.4 Hz, 2 H), 3.91-4.00 (m, 4 H), 6.98 (d, J = 2.4 Hz, 1 H), 7.04 (dd, J_1 = 9.1 Hz, J_2 = 2.4 Hz, 1 H), 7.09 (d, J = 9.1 Hz, 1 H), 7.48 (d, J = 9.2 Hz, 1 H), 7.61 (d, J = 9.1 Hz, 1 H); FD-MS: 440 (M^+).

Example 16: synthesis of compound 16

Compound 15 (20.0 g, 0.045 mol) was dissolved in 200 mL of methylene chloride and cooled to 0°C. To the solution was slowly added boron tribromide (34.45 g (13.0 mL), 0.14 mol). The reaction was stirred for 1 h and quenched carefully with saturated $NaHCO_3$ solution. The reaction was extracted with methylene chloride and the combined organic phase was dried over $MgSO_4$. The crude product was recrystallized from heptane to give 10.2 g (83% yield) of pure product as yellow solid. ^1H NMR $CDCl_3$) δ (ppm): 0.85 (t, J = 7.0 Hz, 3 H), 1.29-1.35 (m, 6 H), 1.77-1.84 (m, 2 H), 3.13 (t, J = 7.4 Hz, 2 H), 5.04 (br, 1 H), 7.10-7.19 (m, 3 H), 7.72 (d, J =9.9 Hz, 1 H), 7.94 (d, J = 9.3 Hz, 1 H), 12.75 (s, 1 H); FD-ES: 273 $(M + 1)^+$.

Example 17: synthesis of compound 17

Compound 16 (30.02 g, 0.11 mol) was dissolved in 200 mL of acetone. To the solution was added potassium carbonate (38.05 g, 0.28 mol) and catalytic amount of 18-crown-6. The mixture was stirred for 5 min. and benzyl bromide (47.2 g, 0.28 mol) was added. The reaction was heated to reflux for 2 h and then solvent was removed. The residue was extracted with methylene chloride/water. Pure product was obtained by recrystallization using heptane (40.1 g, 80% yield). ^1H NMR $CDCl_3$) δ (ppm): 0.72 (t, J = 7.4 Hz, 3 H), 1.12-1.19 (m, 6 H), 1.52-1.61 (m, 2 H), 2.78 (t, J = 7.5 Hz, 2 H), 5.01 (s, 2 H), 5.04 (s, 2 H), 7.03 (d J = 2.5 Hz, 1 H), 7.09 (d, J = 9.4 Hz, 1 H), 7.10 (d, J = 9.1 Hz, 1 H), 7.18-7.34 (m, 10 H), 7.46 (d, J = 9.2 Hz, 1 H), 7.56 (d, J = 9.1 Hz, 1 H); FD-ES: 453 $(M + 1)^+$.

Example 18: synthesis of compound 18

Compound 17 (16.0 g, 0.035 mol) was dissolved in 200 mL of toluene. To the solution was added anhydrous magnesium bromide/ether complex (9.12 g, 0.035 mol). The reaction was refluxed overnight. The reaction was cooled and water was added. The organic phase was separated and the aqueous phase was extracted with ether. The combined organic phase was dried over $MgSO_4$. The pure product was obtained by column chromatography on silica gel using heptane/ether as an eluent (11.5 g, 90% yield). ^1H NMR $CDCl_3$) δ (ppm): 0.85 (t, J = 7.0 Hz, 3 H), 1.29-1.35 (m, 6 H), 1.77-1.84 (m, 2 H), 3.08 (t, J = 7.4

Hz, 2 H), 5.11 (s, 2 H), 7.93-7.46 (m, 8 H), 7.68 (d, J =9.1 Hz, 1 H), 7.92 (d, J = 9.2 Hz, 1 H), 12.74 (s, 1 H); FD-MS: 362 (M^+).

Example 19: synthesis of compound 19

Compound 18 (3.02 g, 0.0083 mol) was dissolved in 30 mL of methylene chloride and cooled to 0 °C. To this solution was added triethylamine (1.01 g, 0.0099 mol) and trifluoromethane sulfonic anhydride (2.85 g, 0.01 mol) was added dropwise. After 20 min, the reaction was quenched by water and extracted with methylene chloride. The pure product was obtained by passing through a short silica gel column (4.0 g, quantitative yield). FD-MS: 494 (M^+).

Example 20: synthesis of compound 20

Compound 6 (9.27 g, 0.033 mol) and compound 19 (15.0 g, 0.030 mol) were dissolved in 150 mL of toluene. To this solution was added 2 M Na_2CO_3 (30 mL, 0.060 mol) and a drop of phase transfer reagent Aliquat 336. The mixture was bubbled with nitrogen for 10 min and catalyst $Pd(PPh_3)_4$ (0.52 g, 1.5mol%) was added. The reaction was heated to 105 °C for 3 h and cooled down. The reaction was extracted with methylene chloride and the combined organic phase was dried over $MgSO_4$. The crude product was recrystallized from heptane to give 10.34 g (60% yield) pure product as light yellow solid. FD-MS: 578 (M^+).

Example 21: synthesis of compound 21

Compound 20 (1.0 g, 1.7 mmol) was dissolved in 10 mL of anhydrous THF and cooled to 0 °C. To this cold solution was added $LiAlH_4$ (0.10 g, 2.6 mmol). The reaction was stirred for 20 min and quenched with sodium sulfate decahydrate and then filtered. The precipitate was washed thoroughly with methylene chloride. The filtrate was evaporated to give 0.81 g (81% yield) of pure product as yellow solid. FD-MS: 580 (M^+).

Example 22: synthesis of compound 22

Compound 21 (8.85 g, 0.015 mol) was dissolved in methylene chloride and cooled to 0 °c. To this solution was added dropwise trifluoroacetic acid (2.47 g, 0.022 mol). After 20 min, reaction was quenched with water and extracted with methylene chloride. The pure product was obtained from

recrystallization of the crude product from heptane to give white pulp-like solid (6.36 g, 75% yield). ^{1}H NMR $CDCl_3$) δ (ppm): 0.32-0.37 (m, 2 H), 0.61 (t, J = 7.0 Hz, 3 H), 0.83-0.92 (m, 4 H), 1.26-1.38 (m, 2 H), 2.53-2.55 (m, 2 H), 4.86 (br, 1 H), 5.21 (s, 4 H), 7.25-7.53 (m, 17 H), 7.68 (d, J = 8.3 Hz, 1 H), 7.92 (d, J = 8.3 Hz, 1 H), 8.09 (d, J = 8.8 Hz, 1 H); ^{13}C NMR ($CDCl_3$): 13.87, 22.42, 29.38, 31.29, 33.79, 46.36, 70.06, 108.61, 118.85, 119.26, 125.45, 125.81, 126.73, 127.62, 128.03, 128.63, 133.96, 136.94, 137.77, 143.45, 155.95; FD-MS: 562 (M^+).

Example 23: synthesis of compound 23

Compound 22 (1.0 g, 1.78 mmol) was suspended in 2 mL of DMSO. The suspension was degassed by bubbling nitrogen for 5 min. and 50% NaOH aqueous solution (0.28 g, 3.56 mmol) and a drop of phase transfer reagent Aliquat® 336, followed by slow addition of n-hexylbromide (0.35 g, 2.13 mmol). The reaction turned into bright orange upon addition of NaOH, and changed into light yellow when n-hexylbromide was added. The reaction was heated to 80 °C for 20 min. during which the reaction became clear light yellow solution. The reaction was poured into water, extracted with ether and dried to give quantitative pure product as off-white solid. ^{1}H NMR $CDCl_3$) δ (ppm): 0.21-0.25 (m, 4 H), 0.59 (t, J = 7.0 Hz, 6H), 0.74-0.92 (m, 8 H), 1.26-1.34 (m, 4 H), 2.65-2.70 (m, 4 H), 5.19 (s, 4 H), 7.30-7.44 (m, 10 H), 7.51 (d, J = 7.2 Hz, 4 H), 7.77 (d, J = 8.3 Hz, 2 H), 7.90 (d, J = 8.3 Hz, 2 H), 8.30 (d, J = 9.2 Hz, 2 H); ^{13}C NMR ($CDCl_3$): 13.83, 22.36, 23.54, 29.39, 31.15, 40.12, 59.95, 69.99, 109.15, 118.58, 118.77, 124.67, 125.38, 127.11, 127.64, 128.01, 128.60, 134.65, 136.92, 137.48, 145.14, 155.54; FD-MS: 646 (M^+).

Example 24: synthesis of compound 24

Compound 23 (1.0 g, 1.5 mmol) was dissolved in 30 mL of methylene chloride and cooled to 0 °C. To this solution was added boron tribromide (0.85 g, 3.4 mmol) dropwise. After 30 min, the reaction was quenched with saturated sodium bicarbonate. The aqueous layer was extracted with methylene chloride and the combined organic layer was washed with water and dried over $MgSO_4$. The crude product was washed with minimum amount of methylene chloride to 0.41 g give pure product as light tan solid and the filtrate

was purified by column chromatography on silica gel using ether/heptane as an eluent to give 0.19 g of product (total yield 74%). ^{1}H NMR ($CDCl_3$) δ ppm: 0.18-0.28 (m, 4 H), 0.60 (t, J = 7.0 Hz, 6 H), 0.74-0.98 (m, 8 H), 1.12-1.31 (m, 4 H), 2.63-2.68 (m, 4 H), 5.08 (br, 2 H), 7.20 (dd, J_1 = 9.1 Hz, J_2 = 2.6 Hz, 2 H), 7.30 (d, J = 2.6 Hz, 2 H), 7.73 (d, J = 8.4 Hz, 2 H), 7.89 (d, J = 8.4 Hz, 2 H); FD-MS: 466 (M^+).

Example 25: synthesis of compound 25

Compound 24 (1.0 g, 2.14 mmol) was dissolved in methylene chloride and cooled to 0 °C. To the solution was added triethylamine (0.54 g, 5.36 mmol) followed by slow addition of trifluoromethanesulfonic anhydride (1.51 g, 5.36 mmol). The reaction was stirred at room temperature for 30 min and quenched with water. The reaction was extracted with methylene chloride and the organic phase was dried with $MgSO_4$. The crude product was recrystallized from heptane to give 1.1 g pure product as light yellow crystals (70% yield). ^{1}H NMR ($CDCl_3$) δ ppm: 0.13-0.23 (m, 4 H), 0.59 (t, J = 7.0 Hz, 6 H), 0.74-0.89 (m, 12 H), 2.66-2.72 (m, 4 H), 7.50 (dd, J_1 = 9.3 Hz, J_2 = 2.5 Hz, 2 H), 7.90 (d, J = 2.6 Hz, 2 H), 7.97 (d, J = 8.4 Hz, 2 H), 8.09 (d, J = 8.4 Hz, 2 H), 8.44 (d, J = 9.4 Hz, 2 H); 13.74, 22.24, 23.39, 29.13, 31.04, 40.06, 60.53, 119.88, 120.07, 121.18, 125.61, 128.59, 128.81, 133.98, 139.87, 145.87, 146.25, FD-MS: 730 (M^+).

Example 26: synthesis of compound 26

Compound 22 (7.0 g, 12.46 mmol) was suspended in 15 mL of DMSO. The suspension was degassed by bubbling nitrogen for 5 min. and 50% NaOH aqueous solution (1.96 g, 24.92 mmol) and 3 drop of phase transfer reagent Aliquat® 336, followed by slow addition of 2-ethylhexylbromide (2.89 g, 14.94 mmol). The reaction turned into bright orange upon addition of NaOH, and changed into light yellow when 2-ethylhexylbromide was added. The reaction was heated to 80 °C for 20 min. during which the reaction became clear light yellow solution. The reaction was poured into water, extracted with ether and dried to give quantitative 6.8 g of pure product as light yellow viscous oil (92% yield). FD-MS: 674 (M^+).

Example 27: synthesis of compound 27

Compound 26 (8.0 g, 11.87 mmol) was dissolved in methylene chloride and cooled to 0 °C. To the solution was added boron tribromide (7.47 g, 29.68 mmol) dropwise. The reaction was stirred for 20 min. and quenched with saturated Na_2CO_3 solution, and extracted with methylene chloride. The crude product was purified by column chromatography on silica gel using 1/1 methylene chloride/heptane as an eluent to 3.5 g give pure product as light brown solid (60% yield). ^1H NMR ($CDCl_3$) δ ppm: 0.16-0.87 (m, 26 H), 2.62-2.67 (m, 4 H), 7.20 (dd, J_1 = 9.1 Hz, J_2 = 1.3 Hz, 2 H), 7.28 (d, J = 2.6 Hz, 2 H), 7.73 (d, J = 8.3 Hz, 2 H), 7.88 (dd, J_1 = 8.3 Hz, J_2 = 1.2 Hz, 2 H), 8.28 (dd, J_1 = 9.1 Hz, J_2 = 2.6 Hz, 2 H); ^{13}C NMR ($CDCl_3$): 10.34, 13.86, 13.96, 22.46, 22.55, 23.25, 26.51, 27.70, 29.42, 31.22, 32.79, 35.64, 41.18, 43.51, 59.70, 111.47, 111.50, 131.31, 117.33, 117.36, 118.76, 125.35, 125.47, 125.54, .61, 126.68, 126.73, 134.53, 134.62, 137.25, 137.32, 145.34, 145.46, 151.85; FD-MS: 494 (M^+).

Example 28: synthesis of compound 28

Compound 27 (3.50 g, 7.1 mmol) was dissolved in 100 mL of methylene chloride and cooled to 0 °C. To this solution was added triethylamine (1.43 g, 14.1 mmol) followed by slow addition of triflic anhydride (4.41 g, 15.6 mmol). The reaction was stirred at room temperature for 20 min. and quenched with water. The reaction was extracted with methylene chloride and the organic phase was dried over $MgSO_4$. The crude product was purified by column chromatography on silica gel using methylene chloride/heptane (5/95) as an eluent to give 2.35 g of pure product as light cream solid (44% yield). ^1H NMR ($CDCl_3$) δ ppm: 0.11-1.26 (m, 26 H), 2.67-2.71 (m, 4 H), 7.50 (d, J = 9.4 Hz, 2 H), 7.89 (d, J = 2.4 Hz, 2 H), 7.97 (d, J = 8.4 Hz, 2 H), 8.08 (d, J = 8.4 Hz, 2 H), 8.45 (d, J = 9.3 Hz, 1 H), 8.47 (d, J = 9.3 Hz, 1 H); ^{13}C NMR ($CDCl_3$): 10.12, 13.50, 13.66, 22.23, 22.36, 22.72, 23.09, 26.56, 27.54, 29.09, 31.03, 32.79, 35.76, 40.96, 43.36, 60.27, 119.74, 120.09, 121.05, 121.13, 126.09, 128.87, 128.97, 133.94, 133.99, 139.91, 139.93, 146.22, 146.33, 146.37, 146.38; FD-MS: 758 (M^+).

Example 29: synthesis of compound 29

To a 500 mL round-bottomed flask was added 200 mL of methylene chloride and phenyldecane (37.6 g, 0.17 mol). The solution was cooled to 0 °C, and aluminum chloride (18.4 g, 0.14 mol) was added in portions, followed by slow addition of o-bromobenzoyl chloride (25.2 g, 0.11 mol). The reaction was stirred at room temperature until completion and cooled to 0 °C and quenched carefully with 2 N HCl solution. The reaction was extracted with methylene chloride, and the combined organic phase was dried over $MgSO_4$. The crude product was purified by column on silica gel to give 41.6 g of product as clear oil (90% yield). FD-MS: m/z 401 (M^+).

Example 30: synthesis of compound 30 (4-(2-ethylhexyloxy)-bromobenzene)

To a 1-L round-bottomed flask were added 4-bromophenol (60.0 g, 0.35 mol), potassium carbonate (52.7 g, 0.38 mol), 2-ethylhexyl bromide (73.7 g, 0.38 mol) and DMF 200 mL. The reaction mixture was stirred at 90 °C under nitrogen overnight. The reaction was poured into water and extracted with ether three times and the combined organic phase was washed with water three times and dried over $MgSO_4$. After solvent was removed, the crude product was obtained as light brown liquid. Pure product was obtained by column chromatography on silica gel using ether/hexane (10/90) as an eluent as a light yellow liquid, 71.2 g (72% yield). ^1H NMR ($CDCl_3$) δ (ppm): 0.88-0.93 (m, 6H, CH_3), 1.27-1.46 (m, 8H), 1.65-1.74 (m, 1H), 3.78 (d, J = 5.7 Hz, 2H, OCH_2), 6.76 (d, J = 8.9 Hz, 2H), 7.33 (d, J = 8.9 Hz, 2H); ^{13}C NMR ($CDCl_3$): 11.08, 14.08, 23.03, 23.80, 29.05, 30.46, 39.29, 70.72, 112.42, 116.29, 132.11, 158.47; FD-MS: m/z 285 (M^+).

Example 31: synthesis of compound 31 (2,6-bis(t-butyldimethylsilyloxy)anthraquinone)

To a 2-L round-bottomed flask were added 2,6-dihydroxyanthraquinone (80.0 g, 0.33 mol), imidazole (108.8 g, 1.6 mol), t-butyldimethylsilyl chloride (115.5 g, 0.77 mol), and DMF 600 mL. The dark red mixture was heated to 90 °C for 3 h. TLC indicated the completion of the reaction. The reaction was cooled down and poured into 2 L of cool water.

The dark green needle like precipitate was filtered off and washed with water and methanol. The dark green crystals were dissolved in ether and the black insoluble part was filtered off. The bright yellow filtrate was concentrated and the crude product was suspended in boiling methanol and filtered to give pure 85.1 g product as yellow silky crystals (54% yield). ^{1}H NMR ($CDCl_3$) δ (ppm): 0.28 (s, 12H), 1.00 (s, 18H), 7.14 (dd, J_1 = 8.5 Hz, J_2 = 2.5 Hz, 2H), 7.64 (d, J = 2.5 Hz, 2H), 8.17 (d, J = 8.5 Hz, 2H); ^{13}C NMR ($CDCl_3$): -4.36, 25.53, 117.35, 125.34, 127.57, 129.73, 135.73, 161.26, 182.17; M.p. 131-133 °C; FD-MS: m/z 468 (M^+).

Example 32: synthesis of compound 32 (2,6-dihydroxy-9,10-di(4-(2-ethylhexyloxy)phenyl)anthracene)

Compound 30 (18.3 g, 0.064 mol) was dissolved in 60 mL of anhydrous THF and cooled to –78 °C. To this solution was added n-BuLi (2.5 M in hexane, 25.6 mL, 0.064 mol) slowly to maintain the temperature below –60 °C. After addition, the orange-yellow solution was stirred at –78 °C for an hour. Compound 31 (10.0 g, 0.021 mol) was dissolved in 30 mL of anhydrous THF and added dropwise to the above cooled solution. TLC analysis indicated the completion of the reaction after 3 h. The reaction was warmed up slightly and HI solution (47% in water, 39 mL, 0.21 mol) was added slowly to quench the reaction and to de-protect the TBDMS group. The deep brown reaction was heated to reflux for 10 min. and most of the solvent was removed under reduced pressure. The reaction mixture was then extracted with methylene chloride three times. The combined organic phase was washed with saturated sodium metabisulfate solution, water, and brine, and dried over $MgSO_4$. The crude product was obtained as brown viscous oil and was purified by column chromatography on silica gel with 15/85 ether/hexane as an eluent. The pure product was obtained as light green-yellow solid 5.5 g (42% yield). ^{1}H NMR ($CDCl_3$) δ (ppm): 0.92-1.01 (m, 12H, CH_3), 1.26-1.46 (m, 16H), 1.77-1.86 (m, 2H), 3.96 (d, J = 5.7 Hz, 4H, OCH_2), 4.93 (s, br, 2H, OH), 6.91 (d, J = 2.3 Hz, 2H), 6.95 (dd, J_1 = 9.5 Hz, J_2 = 2.4 Hz, 2H), 7.09 (d, J = 8.6 Hz, 4H, phenyl), 7.31 (d, J = 8.6 Hz, 4H, phenyl), 7.60 (d, J = 9.4 Hz, 2H); ^{13}C NMR ($CDCl_3$): 11.17,

14.13, 23.09, 23.91, 29.13, 30.58, 39.46, 70.62, 106.88, 114.49, 118.59, 127.33, 129.00, 129.93, 131.02, 132.21, 151.75, 158.72; M.p. 195-197 °C; FD-MS: m/z 618 (M^+).

Example 33: synthesis of compound 33 (2,6-di(triflate)-9,10-di(4-(2-ethylhexyloxy)phenyl)anthracene)

Compound 32 (4.5 g, 0.007 mol) was dissolved in 50 mL of dry pyridine and cooled to 0 °C. To this brown red solution was added slowly triflate anhydride (6.2 g, 0.022 mol). The dark green reaction was stirred at room temperature for 20 min. TLC indicated the completion of the reaction. The reaction was poured into water and extracted with ether (3x200 mL). The combined organic phase was washed with 2N HCl (2x200 mL) and dried over $MgSO_4$. The crude product was purified by column chromatography on silica gel using CH_2Cl_2/hexane (10/90) to give 5.9 g of blue fluorescent yellow crystalline product (92% yield). ^{1}H NMR ($CDCl_3$) δ (ppm): 0.94-1.04 (m, 12H, CH_3), 1.38-1.60 (m, 16H), 1.81-1.88 (m, 2H), 4.01 (d, J = 5.7 Hz, 4H, OCH_2), 7.16 (d, J = 8.5 Hz, 4H, phenyl), 7.25 (dd, J_1 = 9.5 Hz, J_2 = 2.4 Hz, 2H), 7.35 (d, J = 8.5 Hz, 4H, phenyl), 7.66 (d, J = 2.3 Hz, 2H), 7.88 (d, J = 9.5 Hz, 2H); M.p. 103-104 °C; FD-MS: m/z 882 (M^+).

Example 34: synthesis of compound 34 (2,6-di(2,2-dimethyltrimethylene diboronate)-9,10-di(4-(2-ethylhexyloxy)phenyl)anthracene)

Compound 33 (4.1 g, 0.005 mol), bis(neopentyl glycolato)diboron (2.3 g, 0.01 mol), 1,1'-bis(diphenylphosphino)ferrocene)dichloropalladium (II)/dichloromethane complex (0.23 g, 6 mol% to compound 33), 1,1'-bis(diphenylphosphino)ferrocene (0.15 g, 6 mol% to 33), and potassium acetate (2.7 g, 0.028 mol) were mixed with 50 mL of dioxane. The mixture was degassed with nitrogen for 10 min. and then heated to 80 °C overnight. The reaction was cooled and ice water 50 mL was added. Brown precipitate formed and was filtered, washed with water, and hexane. The brownish yellow solid was dissolved in ether, washed with water (5x100 mL) to remove the by-product neopentyl glycol to give 3.3 g of product as light brownish yellow solid (88%

yield). ^1H NMR ($CDCl_3$) δ (ppm): 0.94-1.04 (m, 24H, CH_3), 1.21-1.43 (m, 16H), 1.80-1.88 (m, 2H), 3.72 (s, 8H), 4.02 (d, J = 5.7 Hz, 4H, OCH_2), 7.14 (d, J = 8.5 Hz, 4H, phenyl), 7.38 (d, J = 8.5 Hz, 4H, phenyl), 7.62-7.70 (m, 4H), 8.28 (s, 2H); ^{13}C NMR ($CDCl_3$): 11.24, 14.16, 21.95, 23.12, 23.95, 29.20, 30.64, 31.83, 39.57, 70.71, 72.24, 114.38, 126.02, 128.25, 130.20, 130.98, 131.26, 132.38, 132.49, 134.41, 134.52, 137.47, 158.59; M.p. 191-193 °C; FD-MS: m/z 810 (M^+).

Synthesis of Polymers

Example 35: general procedure for synthesis of polymers via the Suzuki coupling reaction

Equal molar of aromatic di-bromide or di-triflate and aromatic di-boron compound, and phase transfer reagent Aliquat® 336 (0.10 equivalent to monomer) were dissolved in of toluene (the ratio of toluene to water (v/v) is about 3/1). To this solution was added 2 M Na_2CO_3 aqueous solution (3.3 equivalent to monomer). The reaction mixture was bubbled with dry nitrogen for 15 min and catalyst tetrakis(triphenylphosphine)palladium (0.03 equivalent to monomer) was added. The reaction was heated under vigorous reflux for 12-24 h, and small amount of phenylboronic acid was added for end-capping of bromo group. The reaction was heated for 5 h and bromobenzene was added to end-cap boronate group. The reaction was heated for another 4 h and then poured into 200 mL of methanol. The precipitated polymer was washed with methanol, diluted HCl solution, and dried. The polymer was treated with diethyl dithiocarbamate twice: polymer was dissolved in toluene, and sodium diethyl dithiocarbamate in water (1 g in 10 mL of water) was added, and the mixture was stirred under nitrogen at 60 °C overnight. The toluene layer was separated and concentrated and the polymer was precipitated into methanol twice. Polymer can then be extracted with acetone with a Sohxlet setup overnight to remove oligomers. Polymer was dried under vacuum at 45 °C.

EL Device Fabrication and Performance

Example 36

An EL device satisfying the requirements of the invention was constructed in the following manner. The organic EL medium has a single layer of the organic compound described in this invention.

a) An indium-tin-oxide (ITO) coated glass substrate was sequentially ultra-sonicated in a commercial detergent, rinsed with deionized water, degreased in toluene vapor and exposed to ultraviolet light and ozone for a few minutes.

b) An aqueous solution of PEDOT (1.3% in water, Baytron P Trial Product AI 4083 from H. C. Stark) was spin-coated onto ITO under a controlled spinning speed to obtain thickness of 500 Angstroms. The coating was baked in an oven at 110 °C for 10 min.

c) A toluene solution of a compound (300 mg in 30 mL of solvent) was filtered through a 0.2 μm Teflon filter. The solution was then spin-coated onto PEDOT under a controlled spinning speed. The thickness of the film was between 500-700 Angstroms.

d) On the top of the organic thin film was deposited a cathode layer consisting of 15 angstroms of a CsF salt, followed by a 2000 angstroms of a 10:1 atomic ratio of Mg and Ag.

The above sequence completed the deposition of the EL device. The device was then hermetically packaged in a dry glove box for protection against ambient environment.

Table 1 summarizes the characterization of the polymers prepared in the present invention. Absorption (AB) and photoluminescence (PL) spectra were obtained from dilute solutions and solid thin films of the polymers and EL spectra were obtained from ITO/PEDOT/organic compound/CsF/Mg:Ag EL devices. The fabrication of EL devices was illustrated in example 36. FIGS. 2 and 5 show the

AB and PL spectra of compounds 231 and 206 respectively. FIGS. 3 and 6 show the EL spectra of compounds 231 and 206 respectively. And the voltage-current characteristics of the EL device of compounds 231 and 206 are shown in FIG. 4 and 7 respectively.

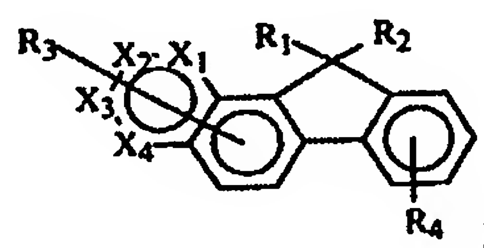
Table 1. Characterization of polymers according to Examples.

Compound	M_w [a]	PDI	T_d (°C)	T_g (°C)	UV [b] (λ_{max} nm)	PL [c] (λ_{max} nm)	EL (λ_{max} nm)
165	16300	1.70	428	183	380	420 (382)	452
167	23200	2.30	441	50	342	396 (342)	412
168	29200	1.97	418	86	376	420 (380)	452
174	34400	2.01	429	138	392	424 (394)	456
190	7000	1.85	426	137	378	424 (394)	476
221	14100	1.80	430	190	362	410 (364)	440
206	38200	2.15	358	NO [f]	392	432 (394)	468
231	39300	2.62	405	123	428	522 (430)	520
215	13100	1.65	433	140	388	426 (384)	456
133	29000	2.27	420	72	358	422 (360)	468
280	976	1.21	278	70	NA [d]	NA	NA
282	4920	1.57	454	182	394 [e]	448 (396) [e]	488
278	2550	1.35	449	128	380 [e]	428 (382) [e]	NA
284	1860	1.28	236	54	368 [e]	430 (370) [e]	NA
198	7990	2.52	436	174	384	448 (386)	452
199	6890	1.50	421	NO	384	424 (386)	NA
201	14100	1.68	405	76	388	450 (378)	460
273	5190	1.38	409	175	364	442 (366)	468

[a] weight average molecular weight, determined by size exclusion chromatography in THF using polystyrene standard. [b] as solid state thin film [c] as solid state thin film, the number in the parenthesis is the excitation wavelength [d] not available [e] in toluene solution. [f] not observed.

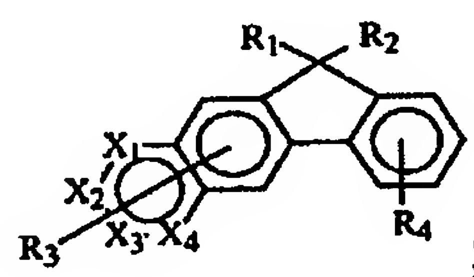
CLAIMS:

1. An organic compound comprising a complex fluorene structure represented by one of the following formulas:



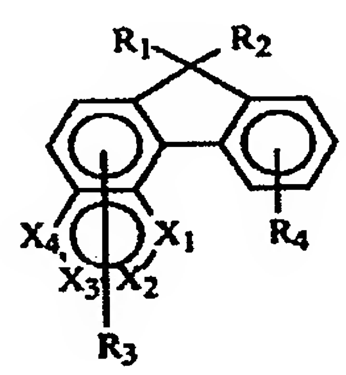
;

(I)



; or

(II)



(III)

wherein:

X_1, X_2, X_3, and X_4 are individually the same or different and include a moiety containing CH or N; R_1, R_2, R_3, and R_4 are substituents each being individually hydrogen, or alkyl, or alkenyl, or alkynyl, or alkoxy of from 1 to 40 carbon atoms; aryl or substituted aryl of from 6 to 60 carbon atoms; or heteroaryl or substituted heteroaryl of from 4 to 60 carbons; or F, Cl, or Br; or a cyano group; or a nitro group; or R_3, or R_4 or both are groups that form fused aromatic or heteroaromatic rings.

2. The organic compound having a complex fluorene structure of claim 1 is a small molecule or a polymer or mixture thereof.

3. The organic compound having a complex fluorene structure of claim 1 is a small molecules represented by formula (IV)

$$(Y_1)y_1 - \underset{\text{(I), (II), or (III)}}{\text{complex fluorene}} - (Y_2)y_2$$

(IV)

wherein Y_1 and Y_2 are each individually represented as a substituted or unsubstituted alkyl, alkenyl, alkynyl, aryl, or heteroaryl or other conjugated groups, and y_1 and y_2 are integers from 0 to 6, and wherein Y_1 and Y_2 are the same or different.

4. The organic compound having a complex fluorene structure of claim 1 is a polymer represented by repeating units of formula (V) or (VI)

$$-\!\left[\underset{\text{(I), (II), or (III)}}{\text{complex fluorene}} - X_5 - Y_1 - X_6\right]\!-$$

; or

(V)

$$\begin{array}{l} -\!\left[\text{polymer main chain}\right]\!- \\ \qquad\quad | \\ \qquad\quad (X_5)x \\ \qquad\quad | \\ \qquad\quad (Y_1)y_1 \\ \qquad\quad | \\ \qquad\quad \text{complex fluorene (I), (II), or (III)} \\ \qquad\quad | \\ \qquad\quad (Y_2)y_2 \end{array}$$

(VI)

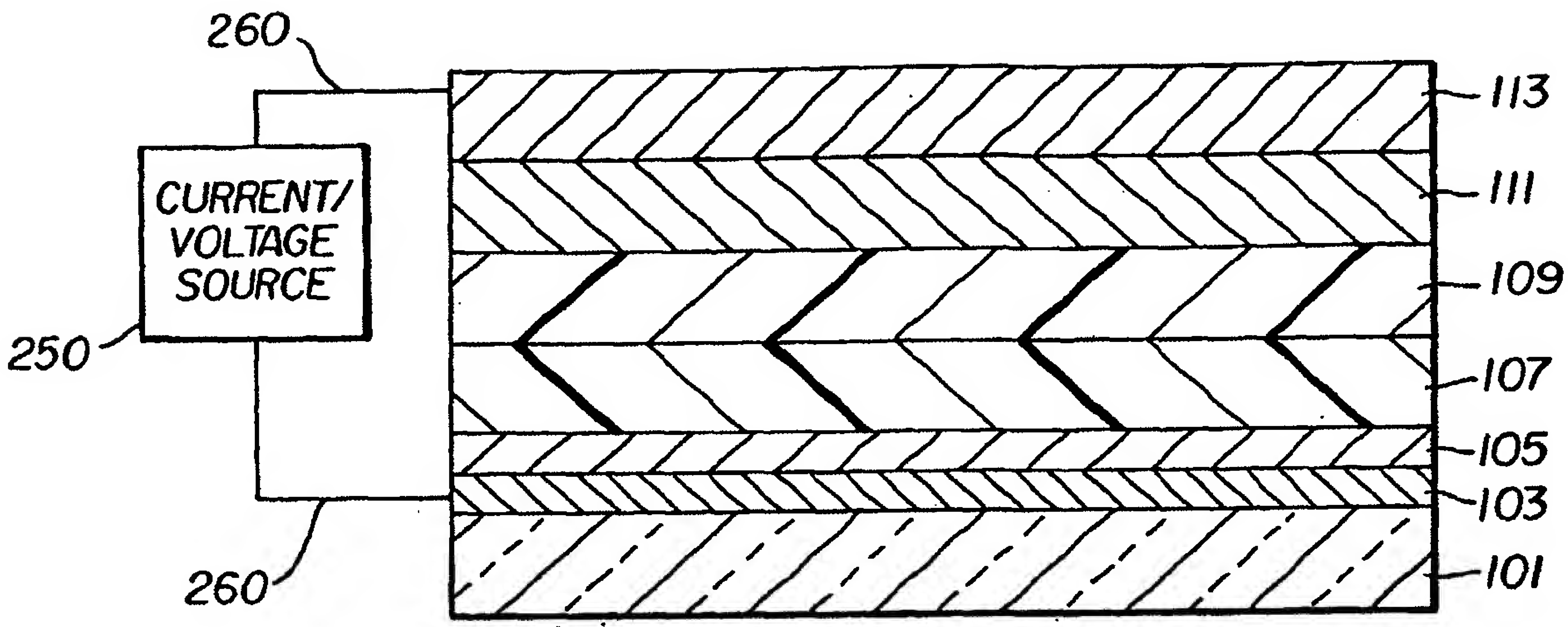
wherein:

X_5 and X_6 are linking groups, Y_1 and Y_2 are each individually represented as a substituted or unsubstituted alkyl, alkenyl, alkynyl, aryl, or heteroaryl or other conjugated groups, x, y_1 and y_2 are integers from 0 to 6, and wherein Y_1 and Y_2 are the same or different.

5. An electroluminescent material comprising one or more organic compound having a complex fluorene structure of claim 1.

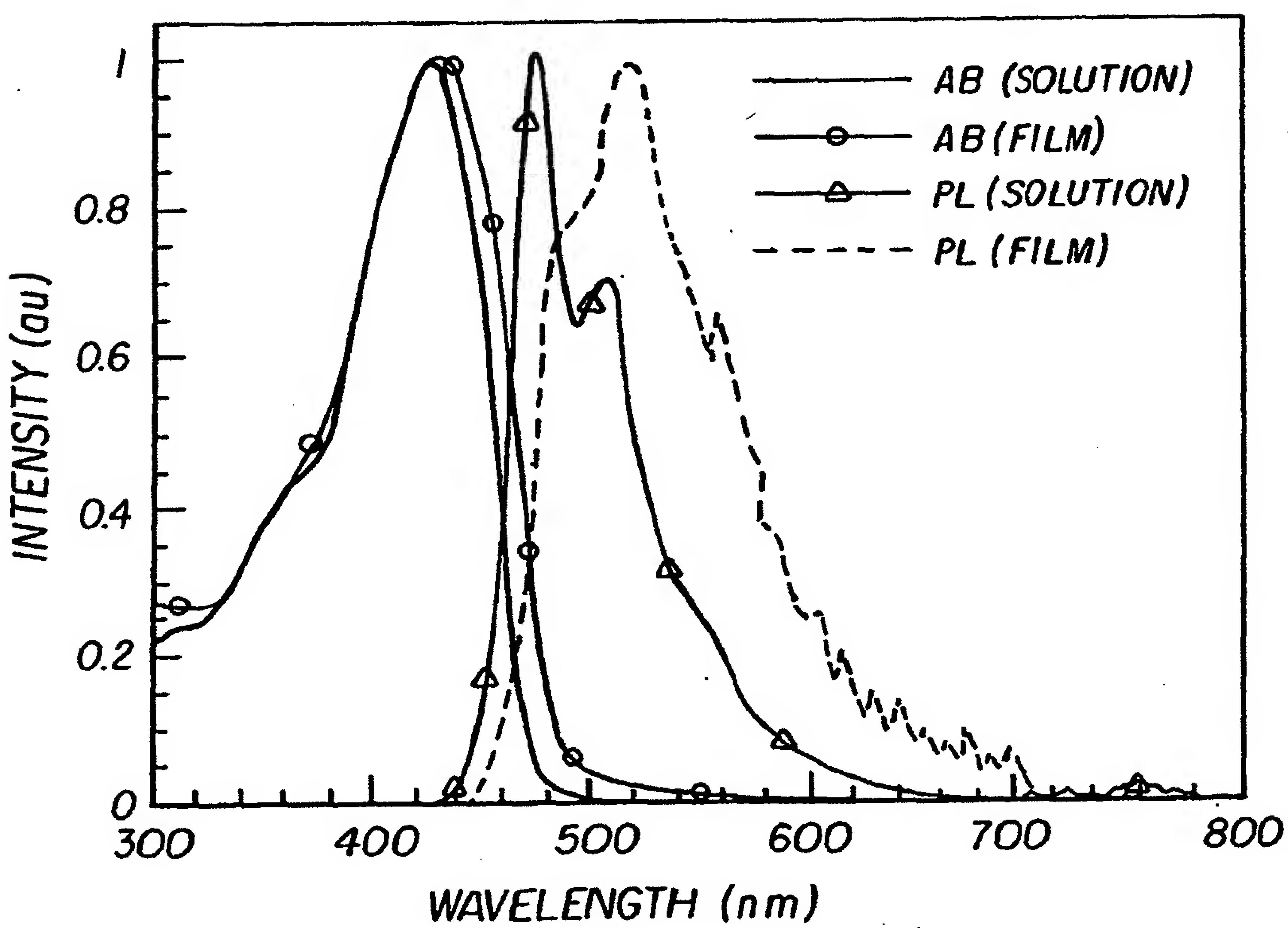
6. A process for producing an electroluminescent material of claim 1, which comprises applying one ore more organic compounds having a complex fluorene structure of claim 1 as a film onto to a substrate which optionally comprises further layers.

7. An electroluminescent device comprising one or more active layers, wherein at least one of these active layers comprises one or more organic compounds having a complex fluorene structure of claim 1.



260
CURRENT/ VOLTAGE SOURCE
250
260
113
111
109
107
105
103
101

FIG. 1



AB (SOLUTION)
AB (FILM)
PL (SOLUTION)
PL (FILM)
INTENSITY (au)
WAVELENGTH (nm)
0
0.2
0.4
0.6
0.8
1
300
400
500
600
700
800

FIG. 2

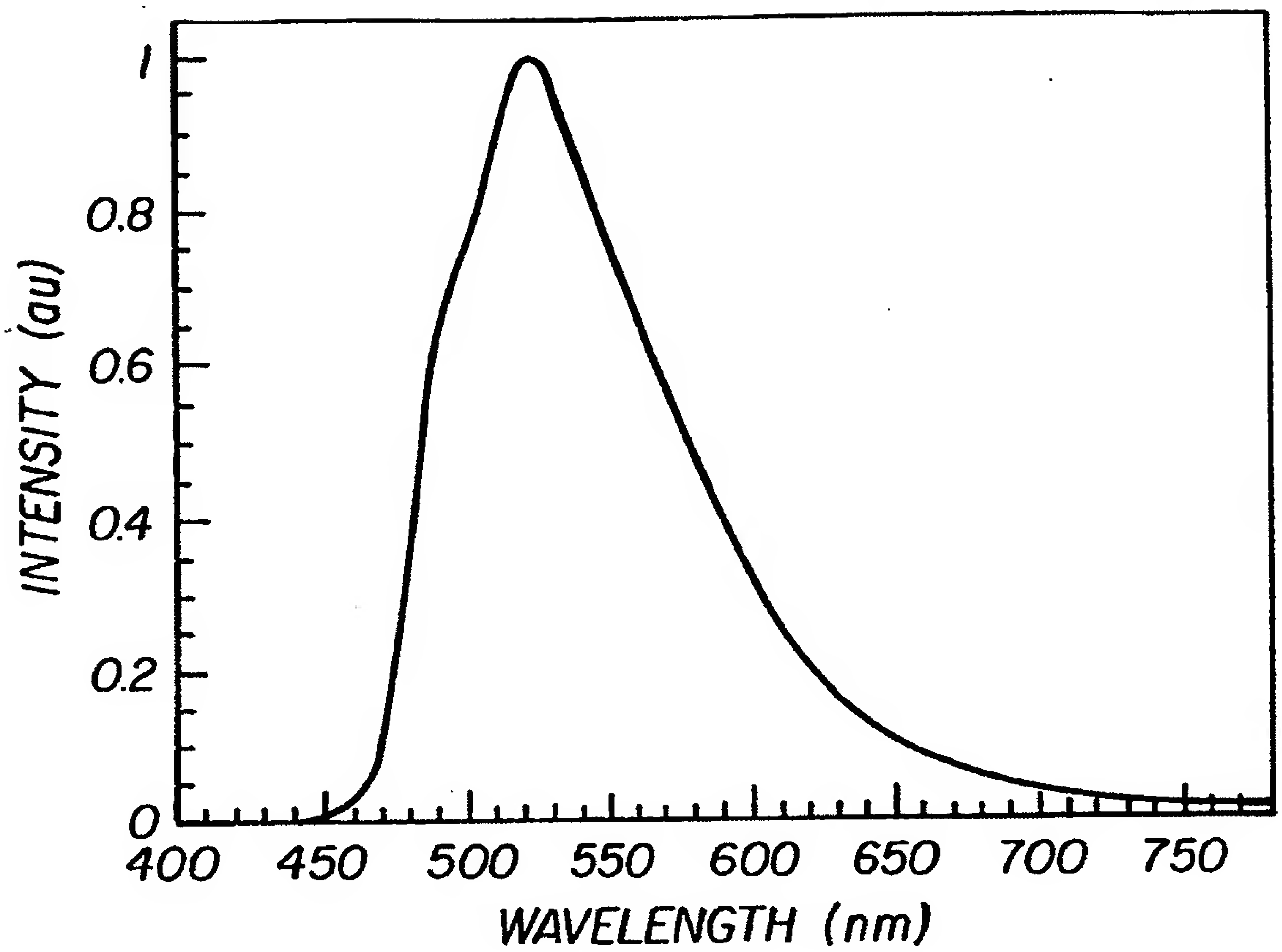

INTENSITY (au)
1
0.8
0.6
0.4
0.2
0
400
450
500
550
600
650
700
750
WAVELENGTH (nm)

FIG. 3

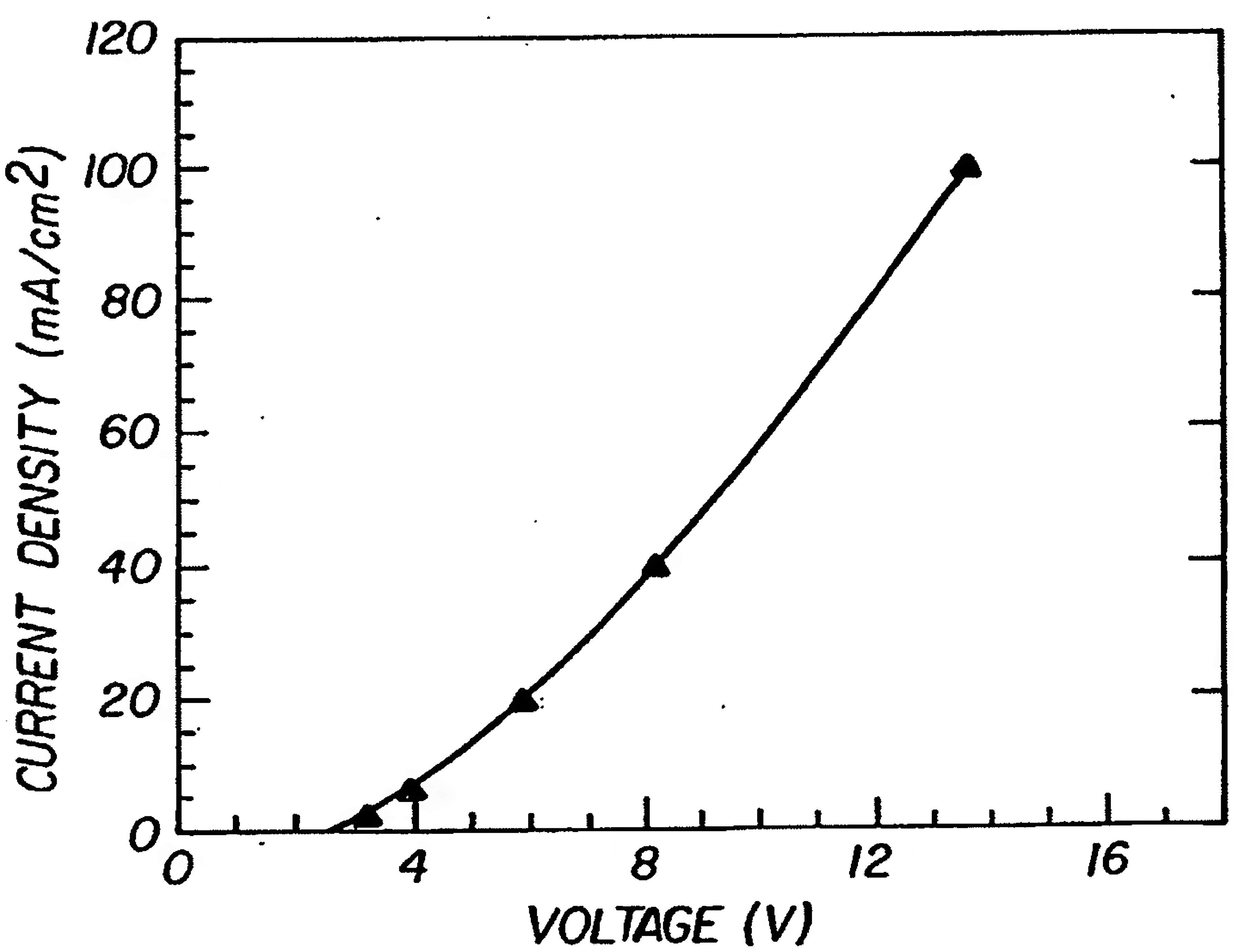

CURRENT DENSITY (mA/cm2)
120
100
80
60
40
20
0
0
4
8
12
16
VOLTAGE (V)

FIG. 4

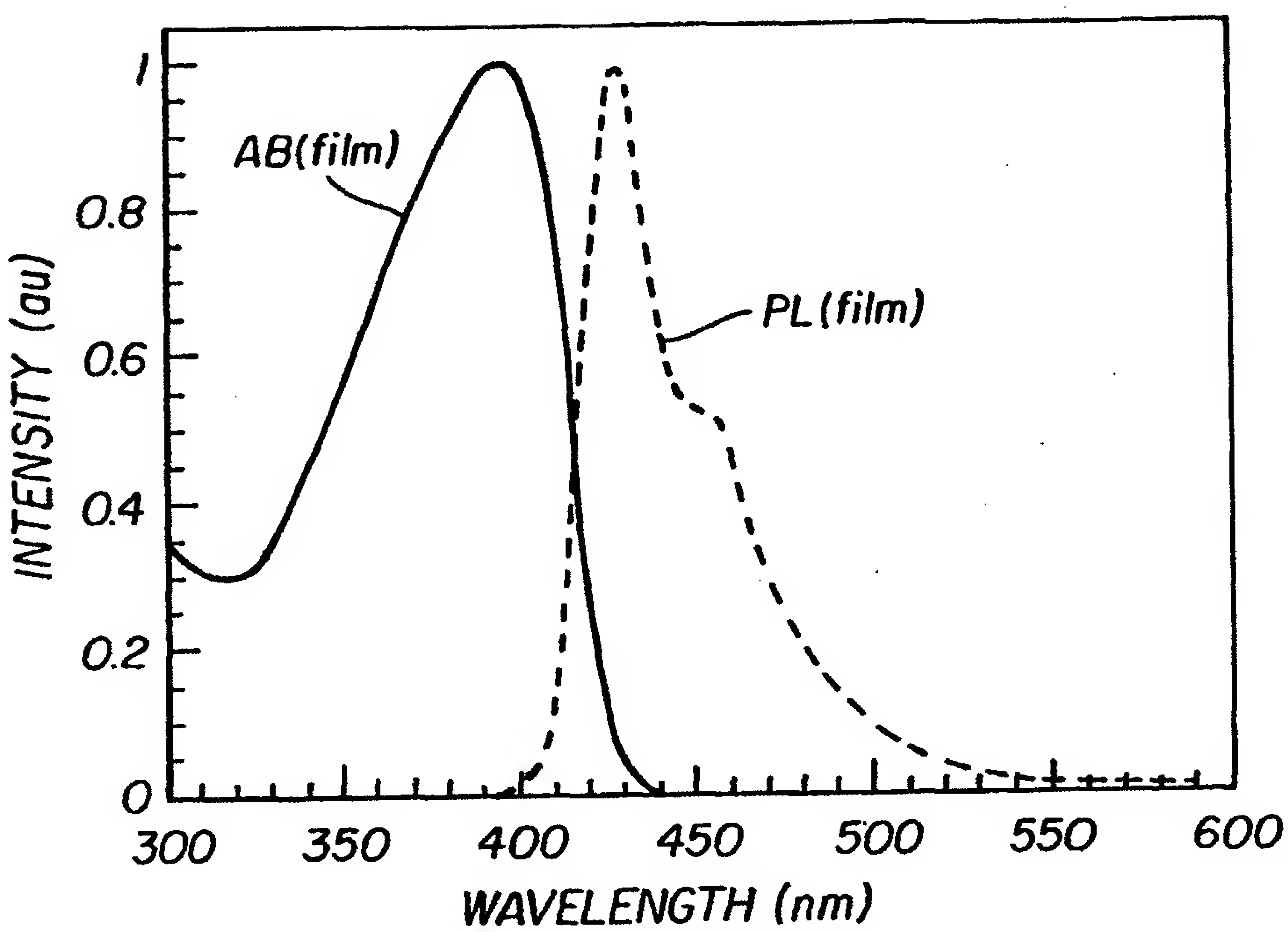

AB(film)
PL(film)
INTENSITY (au)
1
0.8
0.6
0.4
0.2
0
300
350
400
450
500
550
600
WAVELENGTH (nm)

FIG. 5

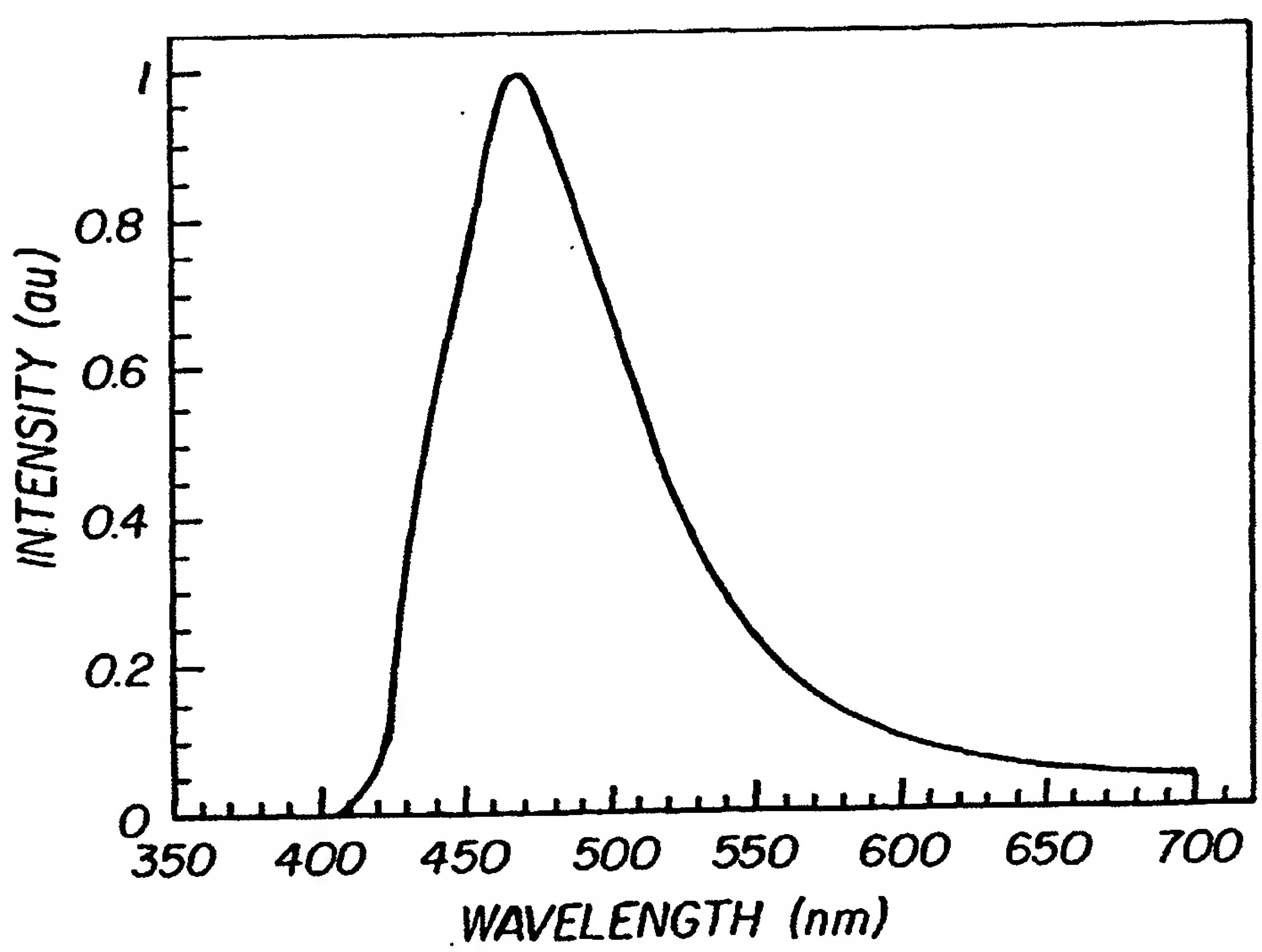

INTENSITY (au)
1
0.8
0.6
0.4
0.2
0
350
400
450
500
550
600
650
700
WAVELENGTH (nm)

FIG. 6

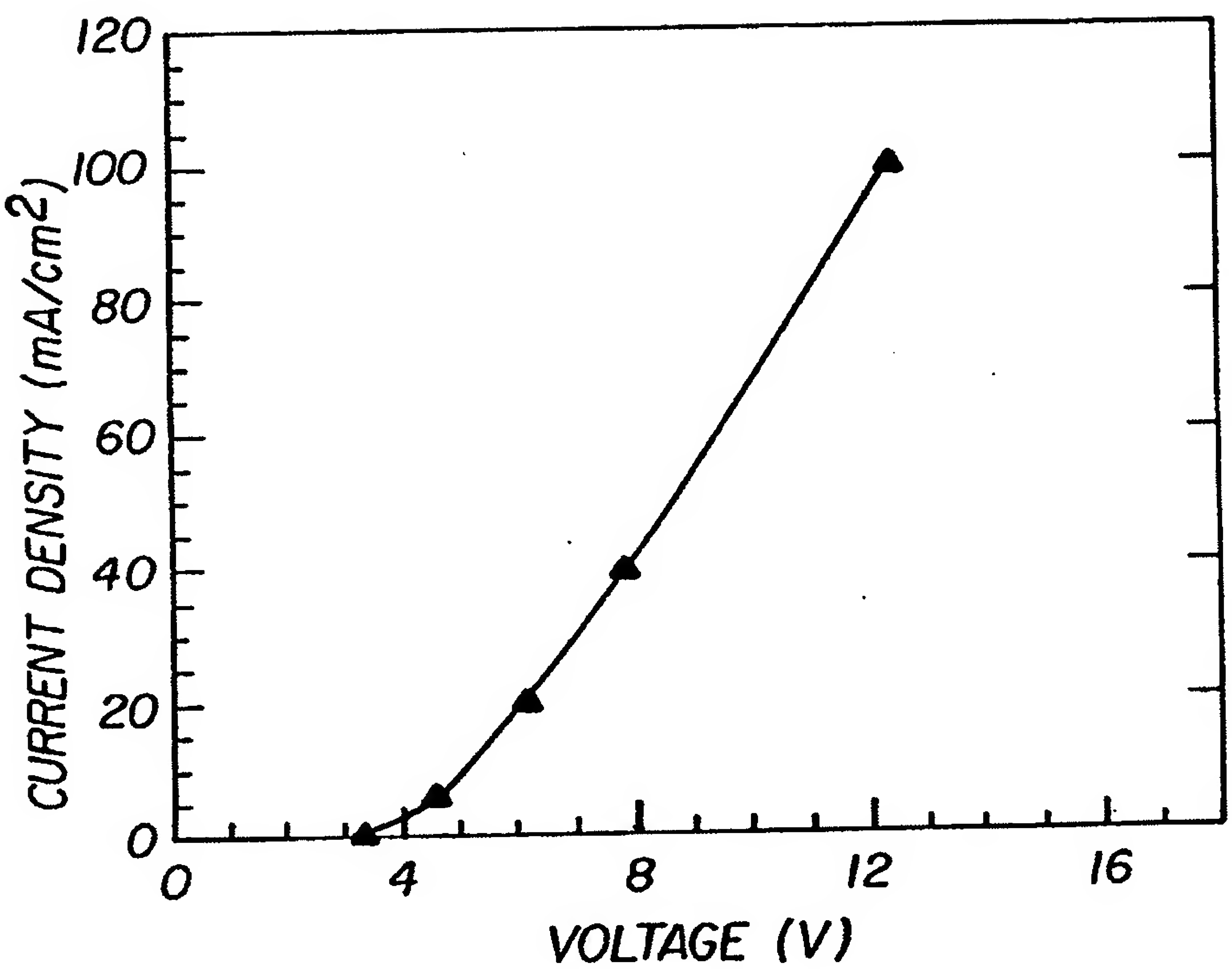


FIG. 7

INTERNATIONAL SEARCH REPORT

tional Application No
PCI/US 03/40731

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C09K11/06 H05B33/14 H01L51/20 H01L51/30 C07C211/54
C07C43/215 C08G61/10 C08G61/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C09K H05B H01L C07C C08G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

CHEM ABS Data, WPI Data, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99/54385 A (DOW CHEMICAL CO) 28 October 1999 (1999-10-28) * pages 4-5, Examples, claims * ---	1-7
X	WO 01/81294 A (SONY INT EUROP GMBH ;MITEVA TZENKA (DE); YASUDA AKIO (DE); KNOLL W) 1 November 2001 (2001-11-01) * pages 10-11, Examples, claims * ---	1-7
X	WO 97/33323 A (UNIAX CORP) 12 September 1997 (1997-09-12) * Examples, claims, figures 1A-1G * ---	1-7
X	WO 01/96454 A (MAXDEM INC ;MARROCCO MATTHEW L III (US); MOTAMEDI FARSHAD J (US)) 20 December 2001 (2001-12-20) * page23, Example 4, page 24, Example 5, page 29, Example 25, claims * ---	1-7

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 May 2004	25/05/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Nemes, C

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 138 746 A (SUMITOMO CHEMICAL CO) 4 October 2001 (2001-10-04) * page 10, chemical formula 41, page 30, Example 6, page 31, Example 7, claims * ---	1-7
P,X	WO 03/051092 A (CANON KK ;CHEN JIAN PING (US)) 19 June 2003 (2003-06-19) * page 13, Example 8, page 14, Example 10, claims * -----	1-7

INTERNATIONAL SEARCH REPORT

International Application No. PCT/ US 03 /40731

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box I.2

The initial phase of the search revealed a very large number of documents relevant to the issue of novelty. So many documents were retrieved that it is impossible to determine which parts of the claims may be said to define subject-matter for which protection might legitimately be sought (Article 6 PCT). For these reasons, a meaningful search over the whole breadth of the claims is impossible. Consequently, the search has been restricted to compounds (I), (II) and (III) of claim 1, wherein X1, X2, X3 and X4 are CH, in combination with the use in an electroluminescent device.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 03/40731

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.:
   because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
   see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 03/40731

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